5.0 ANALYSES OF COLIFORM DATA

Both TC and FC data from the TDH, TWC and predecessor agencies, including the TWQB, (the old Galveston Bay Project) for the Galveston Bay system have been collected and analyzed. The analyses include a check on the frequency and extent of areas exceeding water quality criteria, examination of temporal trends for selected stations, and investigation on the relationship between TC and FC data. The results of these analyses are documented in this section.

5.1 DATA DESCRIPTION

5.1.1 Segmentation of Galveston Bay System

Before coliform data were analyzed, it was noted that some existing TWC water quality segments might be too big to have unique characteristics. For example, Segment 2439 covers lower Galveston Bay including part of the Texas City Harbor and Houston Ship Channels, where water quality varies significantly inside the segment. If coliform data from all stations in Segment 2439 were averaged and analyzed together, the result might not be very meaningful.

According to Ward (1991), there should be two broad objectives for imposing a segmentation system on an estuary. The first objective is administrative; the segmentation may be based on political and geographic boundaries. The second objective is analytical with segmentation criteria being delineation of regions of relative homogeneity in properties. Based on these considerations, and a need to remain consistent with the existing TWC segments, Ward (1991) subdivided TWC segments into quadrilaterals which are listed in Table 5-1. Figure 5-1 shows the quadrilaterals for the open bay areas. The collected coliform data were analyzed based on quadrilaterals developed by Ward. Note that Ward has also developed a set of segments which emphasis homogeneity. These are not employed in this analysis but are used in a data analysis by Ward (1992).

5.1.2 Sources and Types of Coliform Data

There are three major coliform data sources: TWC, TDH, and TWQB. Dr. G. Ward of The University of Texas at Austin has collected, checked, and analyzed these data and has provided these data to EH&A. As part of the QA/QC procedures, EH&A also obtained coliform data directly from TWC and compared them with data provided by Dr. Ward to confirm the identity of the data before they were analyzed.

All three data sources have both TC and FC records. Both TDH and the TWQB data are MPN observation while the MF observations are reported by TWC. Another difference should be noted in the data collecting time. TDH may be more likely to collect data after

TABLE 5–1
QUADRILATERALS IN GALVESTON BAY SYSTEM

Segment	Description
TWC Segment 0801A	– Trinity River Tidal
TWC Segment 0802	– Trinity River Below Lake Livingston
TWC Segment 0901B	– Cedar Bayou Tidal
TWC Segment 0902A	– Cedar Bayou Above Tidal
TWC Segment 0902B	– Cedar Bayou Above Tidal
TWC Segment 1001B	– San Jacinto River Tidal
TWC Segment 1005B	– Houston Ship Channel/San Jacinto River
TWC Segment 1005C	– Houston Ship Channel/San Jacinto River
TWC Segment 1005D	– Houston Ship Channel/San Jacinto River
TWC Segment 1005E	– Houston Ship Channel/San Jacinto River
TWC Segment 1005G	– Houston Ship Channel/San Jacinto River
TWC Segment 1005I	– Houston Ship Channel/San Jacinto River
TWC Segment 1006A	– Houston Ship Channel
TWC Segment 1006B	– Houston Ship Channel
TWC Segment grnsc	– Greens Bayou C
TWC Segment grnsd	– Greens Bayou D
TWC Segment 1007A	– Houston Ship Channel/Buffalo Bayou
TWC Segment 1007C	– Houston Ship Channel/Buffalo Bayou
TWC Segment 1007D	– Houston Ship Channel/Buffalo Bayou
TWC Segment simsb	– Sims Bayou
TWC Segment brays	– Brays Bayou
TWC Segment huntb	– Hunting Bayou
TWC Segment 1013	– Buffalo Bayou Tidal
TWC Segment 1014	– Buffalo Bayou Above Tidal
TWC Segment 1101A	– Clear Creek Tidal
TWC Segment 1101B	– Clear Creek Tidal
TWC Segment 1102	– Clear Creek Above Tidal
TWC Segment 1103	– Dickinson Bayou Tidal
TWC Segment 1104	– Dickinson Bayou Above Tidal
TWC Segment 1105A	– Bastrop Bayou Tidal
TWC Segment 1105B	– Bastrop Bayou Tidal
TWC Segment 1105C	– Bastrop Bayou Tidal
TWC Segment 1105D	– Bastrop Bayou Tidal
TWC Segment 1107	– Chocolate Bayou Tidal
TWC Segment 1113A	– Armand Bayou Tidal
TWC Segment 2421A	– Upper Galveston Bay
TWC Segment 2421B	– Upper Galveston Bay
TWC Segment 2421C	– Upper Galveston Bay
TWC Segment 2421D	– Upper Galveston Bay
TWC Segment 2421E	– Upper Galveston Bay
TWC Segment 2422A	– Trinity Bay
TWC Segment 2422B	– Trinity Bay
TWC Segment 2422C	– Trinity Bay
TWC Segment 2423	– East Bay
TWC Segment 2424A	– West Bay
TWC Segment 2424B	– West Bay

TABLE 5-1
QUADRILATERALS IN GALVESTON BAY SYSTEM
(CONTINUED)

Segment	Description
TWC Segment 2424C – West Bay	
TWC Segment 2424D – West Bay	
TWC Segment 2424E – West Bay	
TWC Segment 2425 – Clear Lake	
TWC Segment 2426A – Tabbs Bay	
TWC Segment 2426B – Tabbs Bay	
TWC Segment 2427 – San Jacinto Bay	
TWC Segment 2428 – Black Duck Bay	
TWC Segment 2429 – Scott Bay	
TWC Segment 2430 – Burnett Bay	
TWC Segment 2431 – Moses Lake	
TWC Segment 2432 – Chocolate Bay	
TWC Segment 2433A – Bastrop Bay/Oyster Lake	
TWC Segment 2433B – Bastrop Bay/Oyster Lake	
TWC Segment 2434 – Christmas Bay	
TWC Segment 2435 – Drum Bay	
TWC Segment 2436 – Barbours Cut	
TWC Segment 2437 – Texas City Ship Channel	
TWC Segment 2438 – Bayport Channel	
TWC Segment 2439A – Lower Galveston Bay	
TWC Segment 2439B – Lower Galveston Bay	
TWC Segment 2439C – Lower Galveston Bay	
TWC Segment 2439D – Lower Galveston Bay	
TWC Segment 2439E – Lower Galveston Bay	
TWC Segment 2439F – Lower Galveston Bay	
TWC Segment 2439G – Lower Galveston Bay	
TWC Segment 2439H – Lower Galveston Bay	

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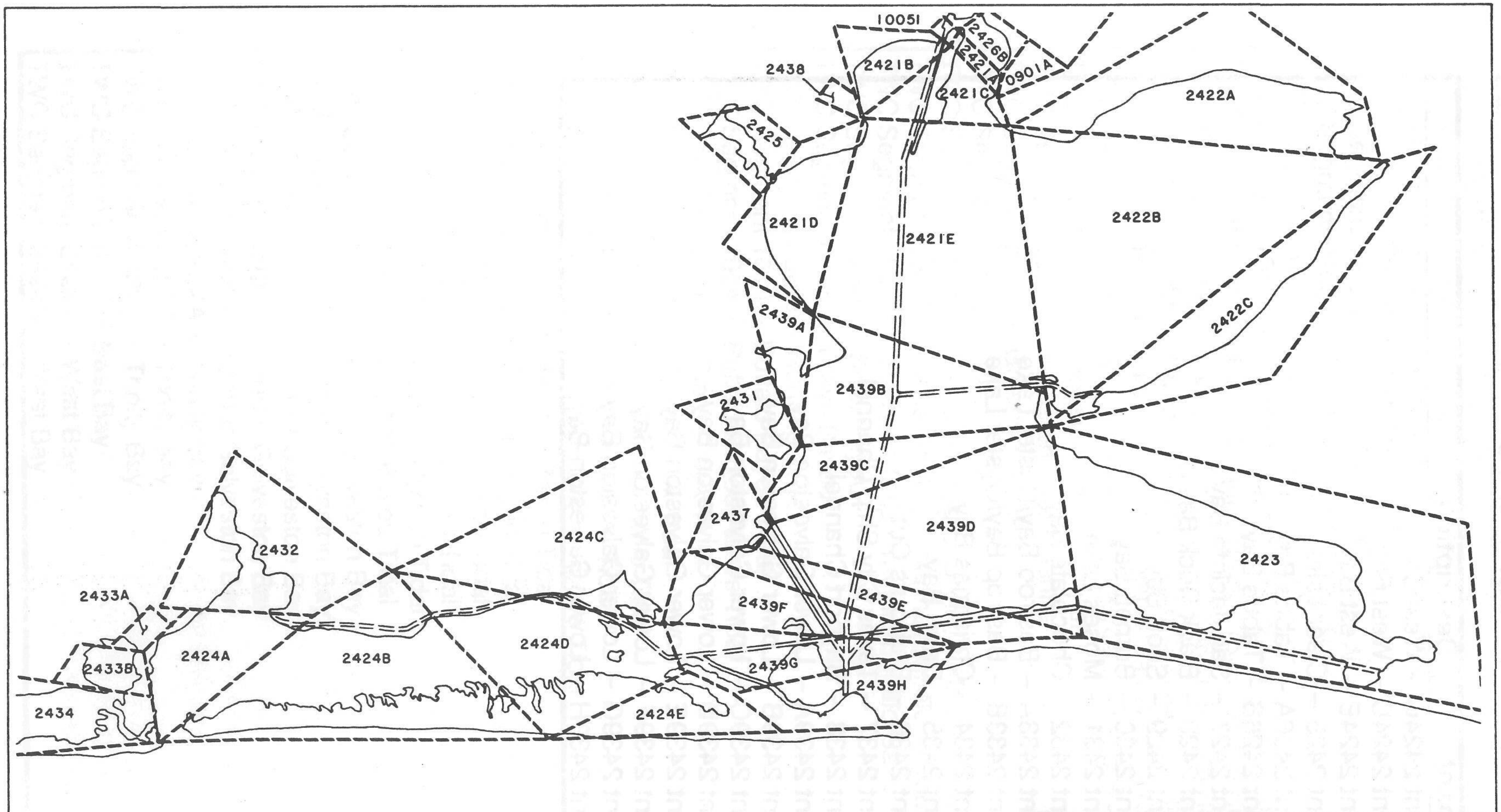

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FIGURE 5-1
QUADRILATERALS
FOR GALVESTON BAY AREAS

rainfalls since their mandate is to characterize coliform levels under "adverse pollution conditions". The TWC and earlier TWQB monitoring have no such requirement. Because of these differences the data will be reported separately. However, no attempt will be made to quantify the possible differences.

The periods of records for data from the three sources are not the same. For TWQB data, they range about from 1965 to 1975 with the greatest sampling intensity during the first GB project. For TDH data, they cover the period from 1950 to present. The TWC data start in about 1980 and continue to present. These differences in time frames provide a comparison among data from the three sources which is illustrated in the following trend analysis section.

TC and FC data also occupy different time frames. The TC data range from about 1950 to 1985. The FC data started in about 1965 up to present. The relationship between TC and FC data is investigated in Section 5.3.

5.2 STATISTICS ON COLIFORM DATA FOR GALVESTON BAY SYSTEM

Table 5-2 presents a statistical summary of FC data for all quadrilaterals in the Galveston Bay system. The first column of Table 5-2 is a list of the quadrilaterals. The second and third columns give the beginning and the ending dates of the available FC data. As can be seen in Table 5-2, most quadrilaterals started having FC data in 1968.

The fourth and fifth columns in Table 5-2 are the total number of FC data and their geometric mean for each quadrilaterals. These mean values represent a long term average of the FC level and can be viewed as a good indication for the average water quality condition in each quadrilateral. From these long-term average values, it can be seen that there are 22 quadrilaterals satisfying the criteria for approved shellfish growing waters, 14 FC/dL. These 22 quadrilaterals cover the open bay 1105c, 2421c, 2421e, 2422a, 2422b, 2422c, 2423, 2424a, 2424b, 2424c, 2424d, 2431, 2433b, 2434, 2435, 2437, 2439a, 2439b, 2439c, 2439d, 2439e, and 2439f (see Figure 5-1). Using the 200 FC/dL criterion for contact recreation, there are 50 quadrilaterals which meet the criterion. In fact, there are only 23 quadrilaterals whose long term mean FC values exceed the contact recreation criteria. These are mainly the urban bayous and waterways in the Houston area: 901b, 1005b, 1005c, 1005d, 1005e, 1005g, 1006a, 1006b, grnsc, grnsd, 1007a, 1007c, 1007d, simsb, brays, huntb, 1013, 1014, 1101a, 1102, 1103, 1104, and 1105a. Thus, from a long term view point, the above areas are not appropriate for recreational activities. Figure 5-2 shows a map of the open bay areas of the Galveston Bay system with the long-term FC geometric mean values.

The sixth column in Table 5-2 lists the number of observations among the total that exceeds the 14 FC/dL criterion, and the seventh column gives the associated percentages.

TABLE 5-2
ANALYSIS OF FECAL COLIFORM DATA

TWC River Segment	Record Period		Total Available Data		Data Exceeded 14 col./100 mL			Data Exceeded 200 col./100 mL		
	Begin YYMMDD	End YYMMDD	No.	Mean*	No.	% Exc	Mean*	No.	% Exc	Mean*
TWC801a	710914	900828	126	67	104	82.5	106	29	23.0	686
TWC802	720412	871215	127	30	80	63.0	81	21	16.5	445
TWC901b	710629	900828	71	262	66	93.0	343	43	60.6	827
TWC902a	730823	900312	60	167	51	85.0	265	26	43.3	948
TWC902b	900828	900828	1	80	1	100.0	80	0	0.0	0
TWC1001b	710726	900118	127	132	107	84.3	210	48	37.8	929
TWC1005b	680716	701020	106	3107	101	95.3	4086	91	85.8	6778
TWC1005c	671001	900813	285	367	256	89.8	557	161	56.5	2057
TWC1005d	720516	720516	1	790	1	100.0	790	1	100.0	790
TWC1005e	720516	720516	1	1300	1	100.0	1300	1	100.0	1300
TWC1005g	680716	720516	104	353	90	86.5	638	59	56.7	2310
TWC1005i	690514	910717	292	37	184	63.0	85	40	13.7	832
TWC1006a	720504	900813	197	1381	190	96.4	1559	162	82.2	2564
TWC1006b	680716	900711	425	1985	406	95.5	2543	336	79.1	5182
TWCgrnsc	730801	870928	120	4506	119	99.2	4836	113	94.2	5820
TWCgrnsd	720808	870928	84	3835	82	97.6	4192	78	92.9	5096
TWC1007a	680716	900813	694	8421	651	93.8	11979	618	89.0	15767
TWC1007c	680716	900813	532	7618	513	96.4	9363	494	92.9	11236
TWC1007d	680716	870928	128	21655	124	96.9	27986	117	91.4	39042
TWCsimsb	711026	870928	62	627	49	79.0	1322	33	53.2	6256
TWCbrays	711026	870928	88	12159	86	97.7	14613	84	95.5	16361
TWChuntb	730801	870928	69	2708	66	95.7	3338	62	89.9	4346
TWC1013	720808	890328	89	18597	89	100.0	18597	89	100.0	18597
TWC1014	730801	890328	205	3848	188	91.7	5360	169	82.4	8783
TWC1101a	701030	890608	77	724	71	92.2	1040	57	74.0	1939
TWC1101b	730919	900910	248	198	216	87.1	315	121	48.8	1178
TWC1102	671001	900910	308	682	294	95.5	834	232	75.3	1522
TWC1103	640305	900710	327	301	309	94.5	370	199	60.9	894
TWC1104	671001	900710	88	580	85	96.6	657	77	87.5	805
TWC1105a	671001	820217	42	419	42	100.0	419	31	73.8	664
TWC1105b	730920	901116	66	153	57	86.4	236	32	48.5	646
TWC1105c	720614	910430	41	11	15	36.6	88	4	9.8	835
TWC1105d	710623	730523	5	56	3	60.0	276	1	20.0	4600
TWC1107	701021	901218	78	80	58	74.4	165	21	26.9	1329
TWC1113a	740409	860206	18	35	11	61.1	114	4	22.2	462
TWC2421a	690514	910717	83	15	38	45.8	85	5	6.0	1095
TWC2421b	680716	910813	274	26	150	54.7	136	54	19.7	1016
TWC2421c	691104	910717	119	8	36	30.3	44	4	3.4	304
TWC2421d	680716	910813	778	15	349	44.9	97	105	13.5	612
TWC2421e	680402	910813	1345	7	324	24.1	51	39	2.9	658
TWC2422a	680820	910717	367	9	129	35.1	58	20	5.4	334
TWC2422b	680402	910717	1281	4	183	14.3	42	19	1.5	384
TWC2422c	680716	910702	314	9	105	33.4	111	35	11.1	568
TWC2423	680716	910729	933	4	139	14.9	50	18	1.9	490

TABLE 5-2
ANALYSIS OF FECAL COLIFORM DATA (CONTINUED)

TWC River	Record Period		Total Available Data		Data Exceeded 14 col./100 mL			Data Exceeded 200 col./100 mL		
Segment	Begin YYMMDD	End YYMMDD	No.	Mean*	No.	% Exc	Mean*	No.	% Exc	Mean*
TWC2424a	680716	910424	298	6	65	21.8	129	27	9.1	645
TWC2424b	710712	910424	363	4	23	6.3	28	0	0.0	0
TWC2424c	730124	910424	283	7	81	28.6	47	8	2.8	575
TWC2424d	680716	910424	912	6	215	23.6	44	21	2.3	497
TWC2424e	730508	901213	491	22	272	55.4	83	66	13.4	600
TWC2425	701030	901210	452	64	313	69.2	157	133	29.4	764
TWC2426a	720516	790516	24	23	9	37.5	90	4	16.7	397
TWC2426b	690514	910717	125	20	60	48.0	90	14	11.2	894
TWC2427	730911	900711	64	34	35	54.7	95	10	15.6	766
TWC2428	730911	900828	52	54	31	59.6	164	14	26.9	520
TWC2429	730911	900711	61	66	50	82.0	100	13	21.3	665
TWC2430	730911	900711	60	56	41	68.3	125	15	25.0	616
TWC2431	680923	900815	278	13	97	34.9	118	37	13.3	632
TWC2432	710623	901218	77	15	28	36.4	97	9	11.7	534
TWC2433a	730124	910424	54	17	26	48.1	109	9	16.7	1016
TWC2433b	720614	910430	84	6	11	13.1	82	2	2.4	885
TWC2434	710623	910430	164	3	7	4.3	49	1	0.6	350
TWC2435	720614	910430	55	5	5	9.1	32	0	0.0	0
TWC2436	730214	900711	55	34	32	58.2	88	4	7.3	1448
TWC2437	710622	910729	125	10	28	22.4	57	5	4.0	632
TWC2438	731105	900719	60	19	22	36.7	64	5	8.3	657
TWC2439a	690520	910813	264	10	89	33.7	115	27	10.2	775
TWC2439b	680402	910813	2250	5	378	16.8	51	59	2.6	388
TWC2439c	680402	910813	603	4	73	12.1	40	7	1.2	363
TWC2439d	680402	910729	618	5	108	17.5	48	10	1.6	440
TWC2439e	680716	910729	150	3	11	7.3	31	0	0.0	0
TWC2439f	680716	910729	231	9	63	27.3	189	29	12.6	1066
TWC2439g	680716	910729	390	80	234	60.0	566	140	35.9	3740
TWC2439h	820921	901113	16	18	5	31.3	114	1	6.3	1000

* Mean = Geometric Mean in colonies/100 mL

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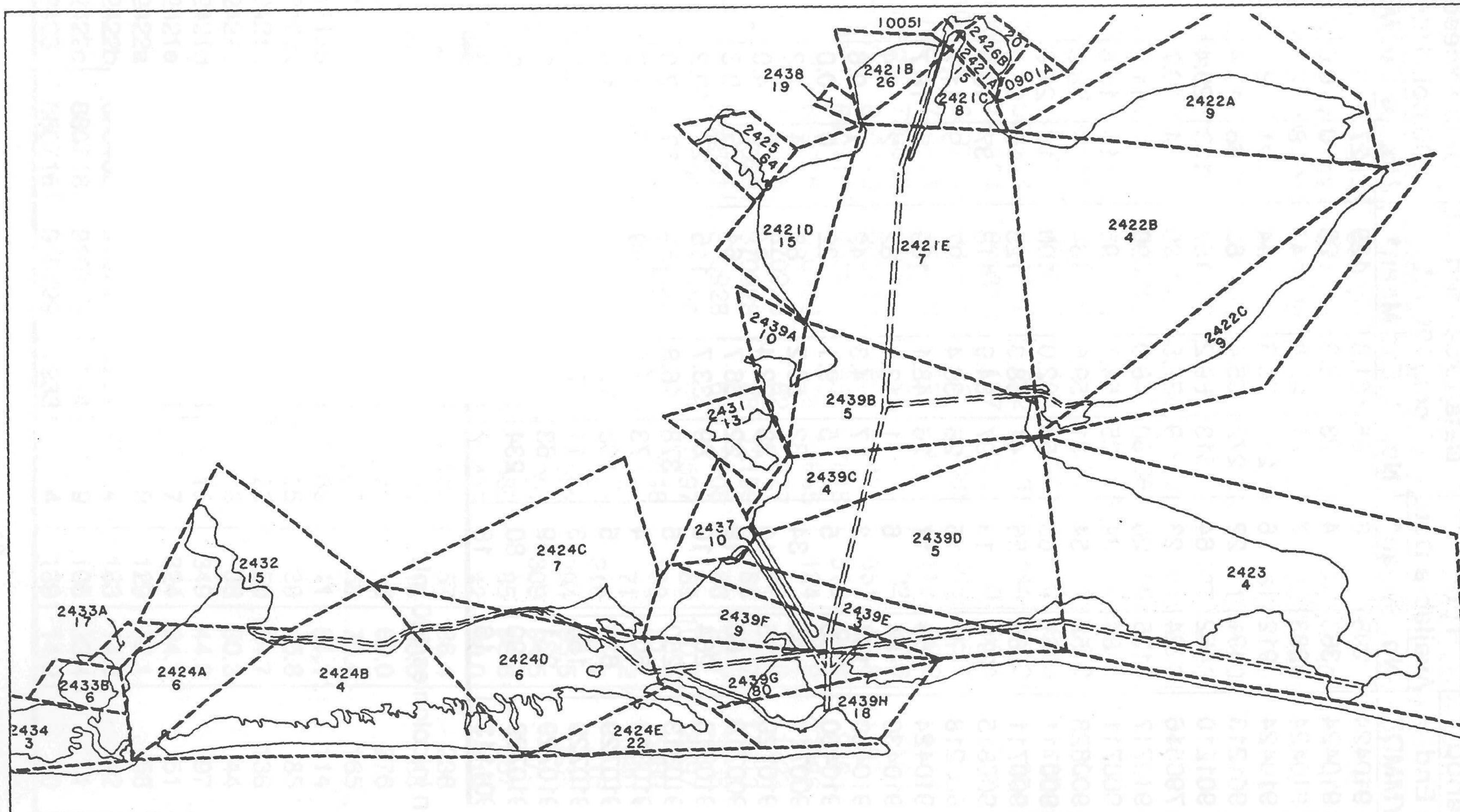

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FIGURE 5-2

LONG-TERM MEAN FECAL

COLIFORM LEVELS IN GALVESTON BAY

The eighth column lists the geometric mean of those data which exceed the 14 criterion for each quadrilateral. The seventh column shows that there are 5 quadrilaterals, namely 902b, 1005d, 1005e, 1013, and 1105a, where the all the data are in excess of 14 FC/dL. However, it must be noted that three of these only have one data value.

While many of the urban bayous have relatively high FC levels, the open bay areas where most of the shellfish reefs are located, i.e. Segments 2421 to 2439, there are nine quadrilaterals with more than 50 percent of their data in excess of the 14 criterion. The remaining 29 quadrilaterals in the open bay areas all have less than 50% of data exceeding the criterion. Figure 5-3 shows the open bay area quadrilaterals with the percentage of data in excess of the 14 FC/dL criterion.

A similar analysis was performed on the data using the 200 FC/dL criterion for recreational waters. The resulting tabulations are listed in the last three columns of Table 5-2. Figure 5-4 shows a map of the open bay areas with the percentage in excess of the 200 FC/dL criterion. As can be seen, there are four quadrilaterals, 0902b, 2424b, 2435, and 2439e, where none of the data exceed the 200 criterion. While 0902b only has one observation the rest have a significant number. At the other extreme, segment 1013, Buffalo Bayou Tidal has all its data exceeding the contact recreation criterion. Five other quadrilaterals have more than 90% of their data exceeding the 200 criterion. However, they all are riverine segments and most of them are located in the Houston area.

5.3 RELATIONSHIP BETWEEN TC AND FC

As a general rule, the TC levels are about five times higher than FC (Kenner, 1978) although a wide spread exists in this ratio. To investigate this ratio, the geometric means of TC and FC data for each quadrilaterals are computed in Table 5-3 with the ratio listed in the last column. As can be seen from the table, the values of the long-term average TC to FC range from 0.8 to 75.1 with an average of 10.6, not 5. In addition to those possible reasons described in Section 2.3, the causes of the wide variations in this ratio include that the data are from different sources, measured by different organizations, measured at different weather conditions, and within different recording periods.

Regression analyses were conducted on the long-term geometric mean TC and FC values. The resulting equation for a linear scale is

$$TC = 3{,}009 + 6.68 * FC$$

with $R^2 = 0.666$. In other words about 66.6% of the TC data variance is explained by FC data and the TC/FC ratio is 6.68. On the other hand, regression on the logarithmic scale gives that

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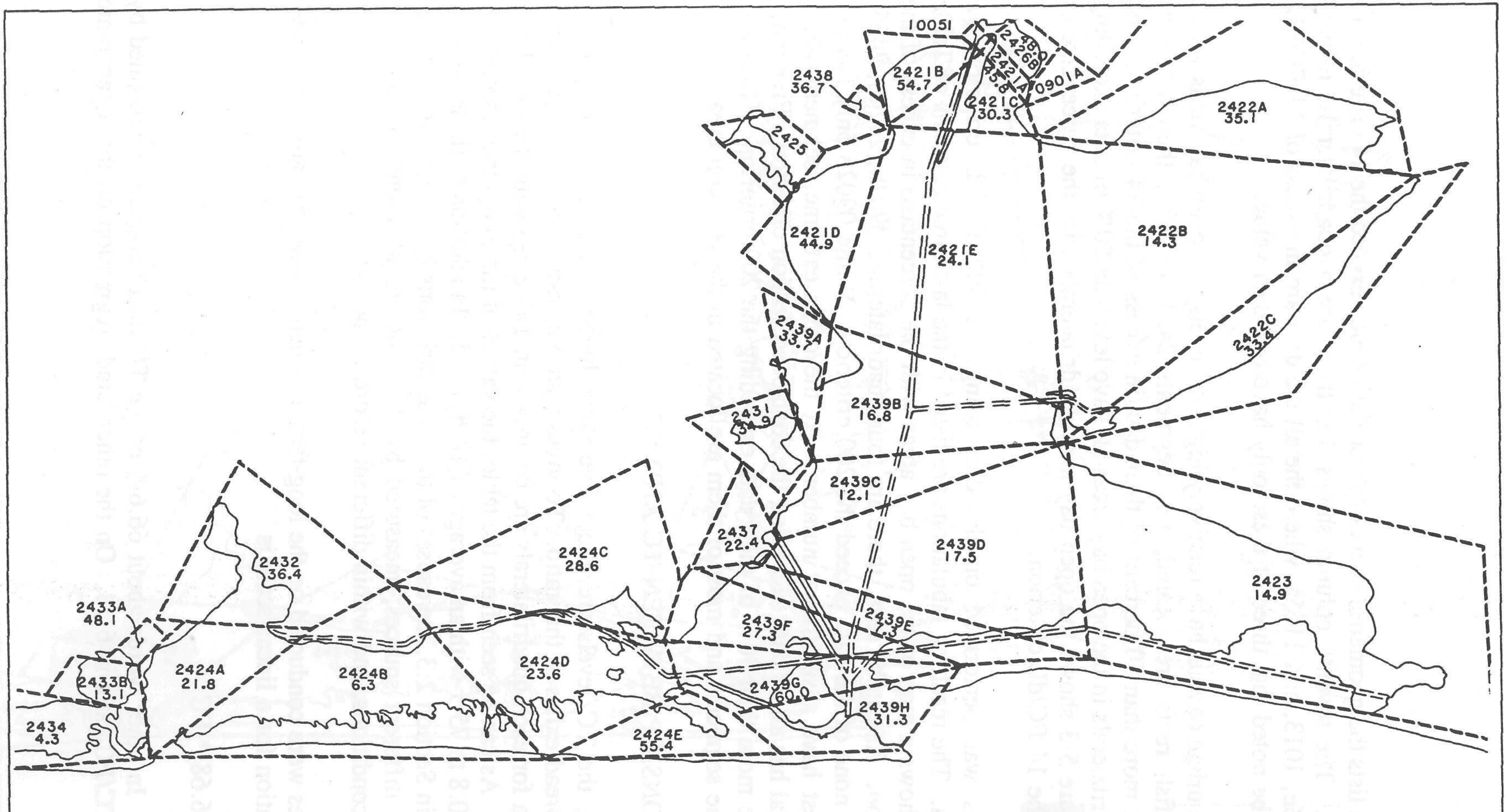

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FIGURE 5-3
PERCENTAGES OF LONG-TERM MEAN
FECAL COLIFORM LEVELS EXCEEDING
14 COLONIES/100mL CRITERION
IN GALVESTON BAY

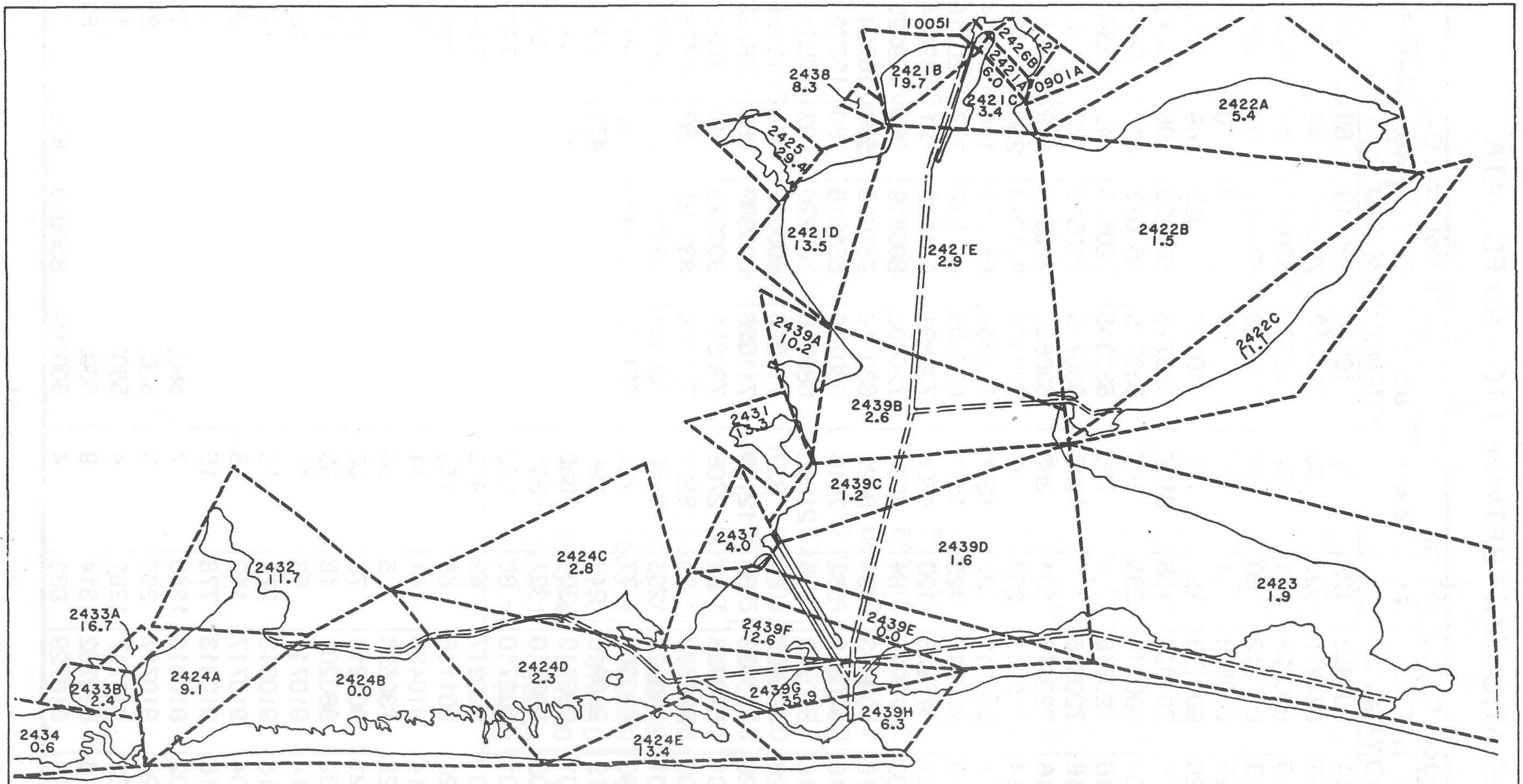

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FIGURE 5-4
PERCENTAGES OF LONG-TERM MEAN FECAL COLIFORM LEVELS EXCEEDING 200 COLONIES/100mL CRITERION IN GALVESTON BAY

TABLE 5-3
RELATIONSHIP BETWEEN TC AND FC DATA

TWC River Segment	Fecal Coliform Data Begin YYMMDD	End YYMMDD	No.	Mean*	Total Coliform Data Begin YYMMDD	End YYMMDD	No.	Mean*	Ratio
TWC801a	710914	900828	126	67	710914	830110	60	1013	15.1
TWC802	720412	871215	127	30	720412	790103	46	136	4.5
TWC901b	710629	900828	71	262	710629	830110	45	8623	32.9
TWC902a	730823	900312	60	167	730823	830110	38	12544	75.1
TWC902b	900828	900828	1	80	0	0	0	0	0.0
TWC1001b	710726	900118	127	132	710726	851018	69	1782	13.5
TWC1005b	680716	701020	106	3107	680716	701020	106	15849	5.1
TWC1005c	671001	900813	285	367	630715	851018	312	6487	17.7
TWC1005d	720516	720516	1	790	630805	720516	45	3344	4.2
TWC1005e	720516	720516	1	1300	630715	720516	48	1556	1.2
TWC1005g	680716	720516	104	353	630820	720516	139	1661	4.7
TWC1005i	690514	910717	292	37	630312	851018	250	484	13.1
TWC1006a	720504	900813	197	1381	720504	851018	138	20254	14.7
TWC1006b	680716	900711	425	1985	630805	851018	398	20118	10.1
TWCgrnsc	730801	870928	120	4506	730801	831128	91	39614	8.8
TWCgrnsd	720808	870928	84	3835	720808	800819	64	29223	7.6
TWC1007a	680716	900813	694	8421	680716	851018	506	167340	19.9
TWC1007c	680716	900813	532	7618	680716	851018	380	137785	18.1
TWC1007d	680716	870928	128	21655	680716	701020	103	98924	4.6
TWCsimsb	711026	870928	62	627	711026	800812	44	10056	16.0
TWCbrays	711026	870928	88	12159	711026	800909	68	88796	7.3
TWChuntb	730801	870928	69	2708	730801	800826	49	29565	10.9
TWC1013	720808	890328	89	18597	720808	831121	52	97731	5.3
TWC1014	730801	890328	205	3848	730801	831121	159	16556	4.3
TWC1101a	701030	890608	77	724	631120	841023	68	9976	13.8
TWC1101b	730919	900910	248	198	630402	851009	476	1966	9.9
TWC1102	671001	900910	308	682	630528	890926	351	15526	22.8
TWC1103	640305	900710	327	301	630605	830726	455	2276	7.6
TWC1104	671001	900710	88	580	640217	830726	79	7229	12.5
TWC1105a	671001	820217	42	419	671001	820217	42	11599	27.7
TWC1105b	730920	901116	66	153	730920	830824	40	5681	37.1
TWC1105c	720614	910430	41	11	680501	810317	23	57	5.2
TWC1105d	710623	730523	5	56	710623	730523	5	79	1.4
TWC1107	701021	901218	78	80	631016	830825	85	794	9.9
TWC1113a	740409	860206	18	35	630418	810224	76	503	14.4
TWC2421a	690514	910717	83	15	631218	810427	62	104	6.9
TWC2421b	680716	910813	274	26	630508	810427	327	141	5.4
TWC2421c	691104	910717	119	8	630717	850806	100	30	3.8
TWC2421d	680716	910813	778	15	580224	850806	618	54	3.6
TWC2421e	680402	910813	1345	7	580224	850806	1011	35	5.0
TWC2422a	680820	910717	367	9	630717	850807	384	84	9.3
TWC2422b	680402	910717	1281	4	580226	850516	1168	18	4.5
TWC2422c	680716	910702	314	9	580226	810406	332	69	7.7
TWC2423	680716	910729	933	4	500309	850909	832	14	3.5

TABLE 5-3
RELATIONSHIP BETWEEN TC AND FC DATA (CONTINUED)

TWC River Segment	Fecal Coliform Data				Total Coliform Data				Ratio
	Begin YYMMDD	End YYMMDD	No.	Mean*	Begin YYMMDD	End YYMMDD	No.	Mean*	
TWC2424a	680716	910424	298	6	630724	801203	304	10	1.7
TWC2424b	710712	910424	363	4	630724	851003	284	6	1.5
TWC2424c	730124	910424	283	7	500320	850923	190	14	2.0
TWC2424d	680716	910424	912	6	500320	890112	549	15	2.5
TWC2424e	730508	901213	491	22	500809	850923	320	66	3.0
TWC2425	701030	901210	452	64	630312	851021	780	668	10.4
TWC2426a	720516	790516	24	23	630820	790516	54	549	23.9
TWC2426b	690514	910717	125	20	630521	851018	92	158	7.9
TWC2427	730911	900711	64	34	730911	851018	40	1004	29.5
TWC2428	730911	900828	52	54	730911	850411	32	933	17.3
TWC2429	730911	900711	61	66	730911	851018	42	1840	27.9
TWC2430	730911	900711	60	56	730911	851018	41	990	17.7
TWC2431	680923	900815	278	13	500831	830504	212	91	7.0
TWC2432	710623	901218	77	15	500414	851022	111	65	4.3
TWC2433a	730124	910424	54	17	501012	801203	24	14	0.8
TWC2433b	720614	910430	84	6	680418	851022	72	26	4.3
TWC2434	710623	910430	164	3	680418	810317	83	5	1.7
TWC2435	720614	910430	55	5	700914	851022	39	18	3.6
TWC2436	730214	900711	55	34	730214	851018	38	490	14.4
TWC2437	710622	910729	125	10	630805	821220	96	50	5.0
TWC2438	731105	900719	60	19	731105	850213	25	352	18.5
TWC2439a	690520	910813	264	10	500227	821221	149	27	2.7
TWC2439b	680402	910813	2250	5	500111	850806	1435	19	3.8
TWC2439c	680402	910813	603	4	500317	850909	385	16	4.0
TWC2439d	680402	910729	618	5	500309	850909	639	15	3.0
TWC2439e	680716	910729	150	3	580312	810310	166	10	3.3
TWC2439f	680716	910729	231	9	500914	821220	342	37	4.1
TWC2439g	680716	910729	390	80	500809	850624	427	460	5.8
TWC2439h	820921	901113	16	18	820427	850923	14	29	1.6
								Average =	10.6

* Mean = Geometric Mean in colonies/dL

$$\text{Log(TC)} = 0.55 + 1.136 * \text{Log(FC)}$$

or

$$TC = 10^{0.55} * FC^{1.136} = 3.55 * FC^{1.136}$$

with $R^2 = 0.861$. This result indicates that the relationship between TC and FC is not linear, with an exponent of 1.136, and that about 86.1% of the TC data variance is related to the FC data. None of these results give a TC/FC ratio of 5.

The relationship between the TC/FC ratio and the geometric mean of the FC data can be observed in Figure 5-5 which shows that for areas with a FC geometric mean greater than about 20, there is extreme scatter. It can be concluded that for areas which have fairly low FC data, such as approved shellfish harvesting areas, the ratio of five is quite reasonable. For areas which have high mean FC levels, the ratio of five is not valid.

While the TC/FC ratio does not appear valid for areas with high FC levels, it is approximately correct for other areas. One advantage to using the TC data is that it allows the period of record to be extended markedly. To take advantage of this longer period of record where appropriate, and to place the two data types in approximately the same scale, a "pseudo" FC is employed. This is simply the TC data divided by five. These will be presented in the following trend analysis.

5.4 TEMPORAL TRENDS

In order to study temporal trends of the data, representative quadrilaterals are selected for more detailed analysis. These are highlighted in Figure 5-6. The criteria for selection are that they have been frequently monitored over a long period and that they cover a range of watershed development activity. Among these, 2439d in East Bay is considered a control area since little development has occurred. Its watershed is primarily agricultural with a limited residential development. Quadrilaterals 2421b and 2421c in upper Galveston Bay near the mouth of Houston Ship Channel and 1005i at the channel mouth are more likely to have changed water quality condition due to urbanization of the western bay area. Also, quadrilaterals 2421d, western side Galveston Bay near Seabrook, 2422a located at upper Trinity Bay, and 2424d at the east end of West Bay, are selected for trend analyses because of their locations, periods of record, and total number of observations available. As listed in Table 5-3, the FC geometric means for quadrilaterals 1005i, 2421b, 2421c, 2421d, 2422a, 2424d, and 2439d are 37, 26, 8, 15, 9, 6, and 5 respectively. Although the first two of these FC mean values exceed 20, which indicates a TC/FC ratio other than 5, TC data for these two quadrilaterals are transformed to pseudo FC so that a rough comparison can be made.

The first dataset considered was the control area, 2439d, in Galveston Bay near East Bay. Results for FC and pseudo FC are shown in Figure 5-7a and 5-7b. It can be seen that

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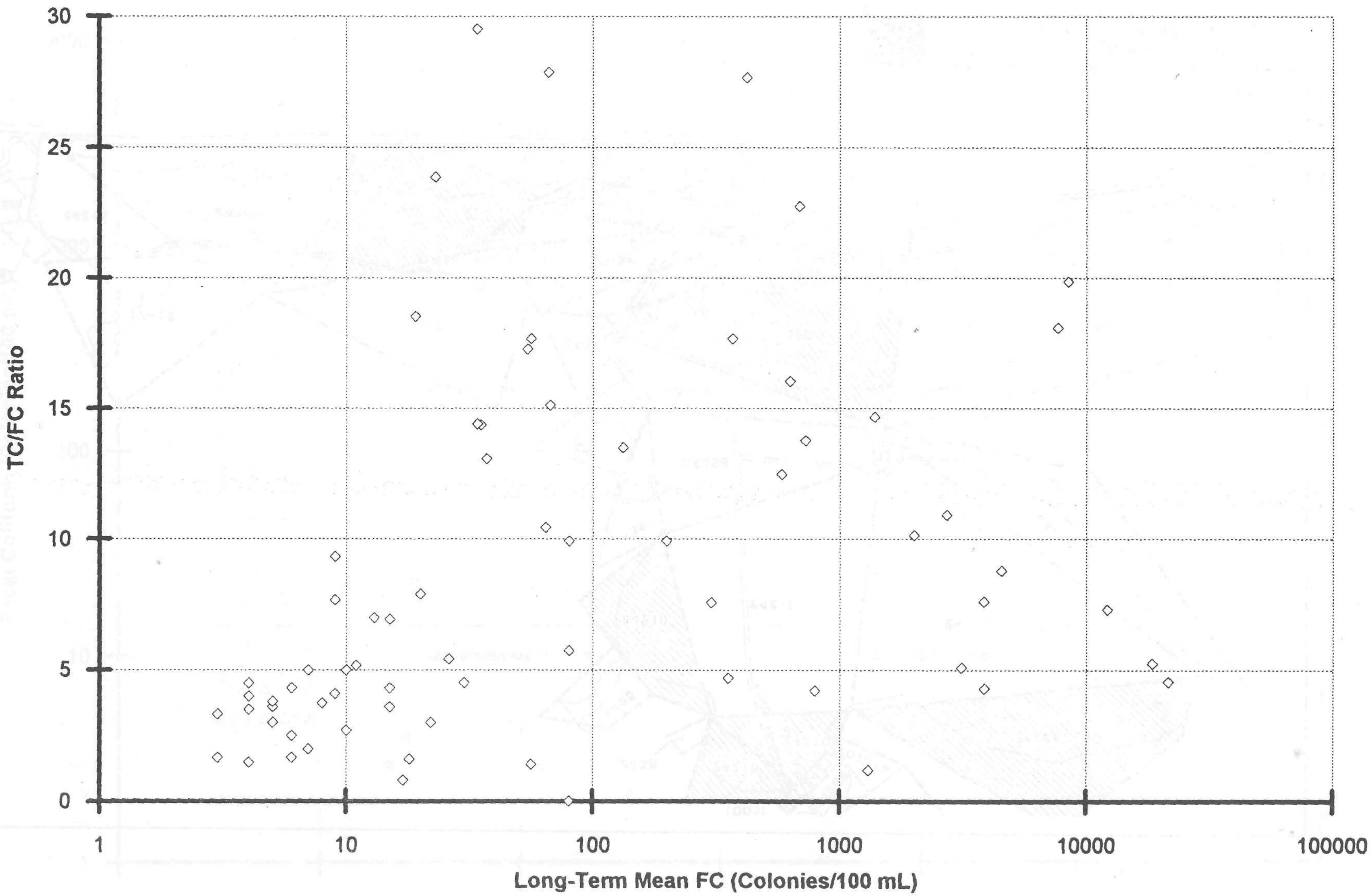
FIGURE 5-5 RELATIONSHIP BETWEEN LONG-TERM MEAN TOTAL AND FECAL COLIFORM LEVELS IN GALVESTON BAY



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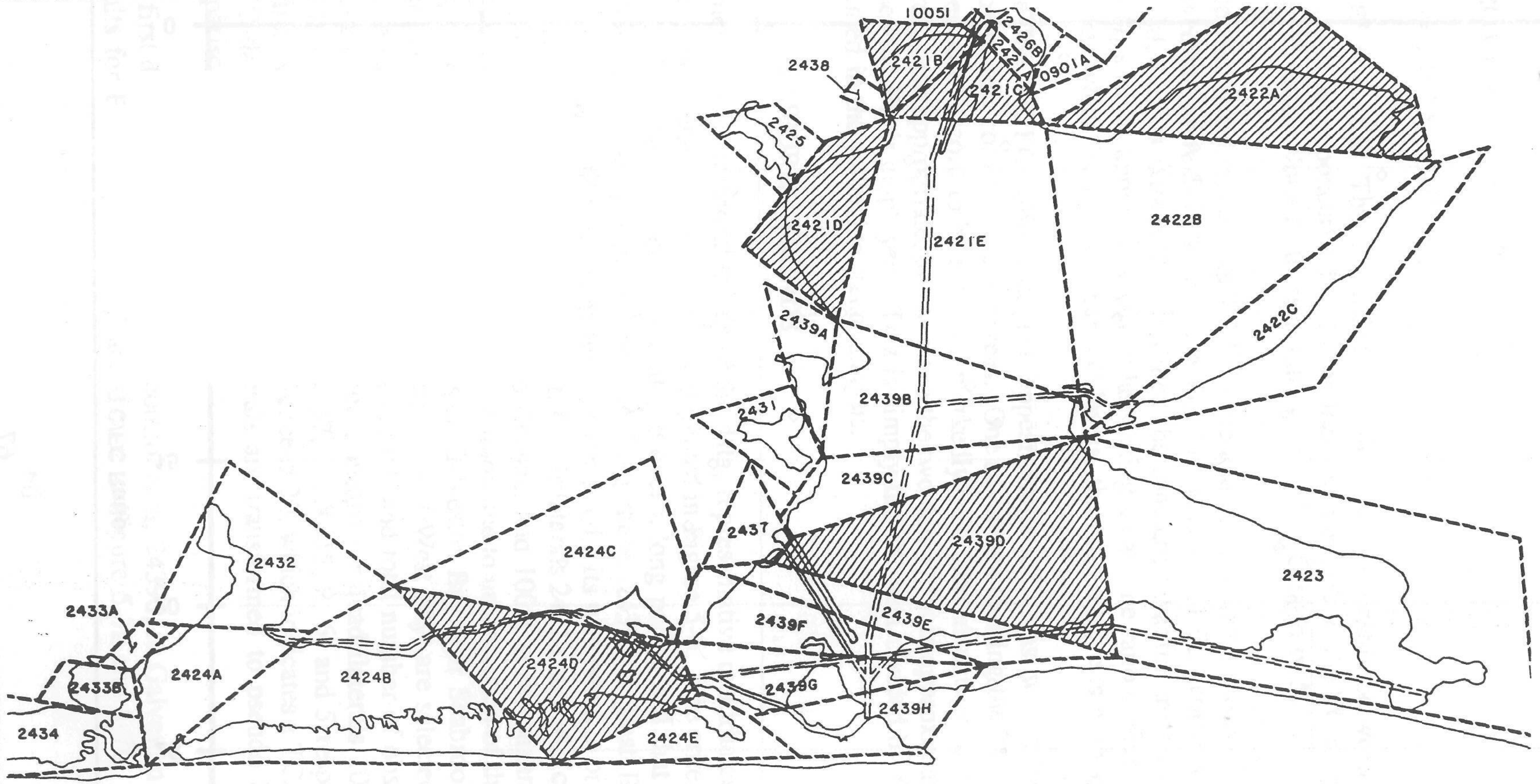

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FIGURE 5-6

QUADRILATERALS SELECTED FOR TREND ANALYSIS

FIGURE 5-7a FECAL COLIFORM DATA FOR QUADRILATERAL 2439d (Lower Galveston Bay Near East Bay)

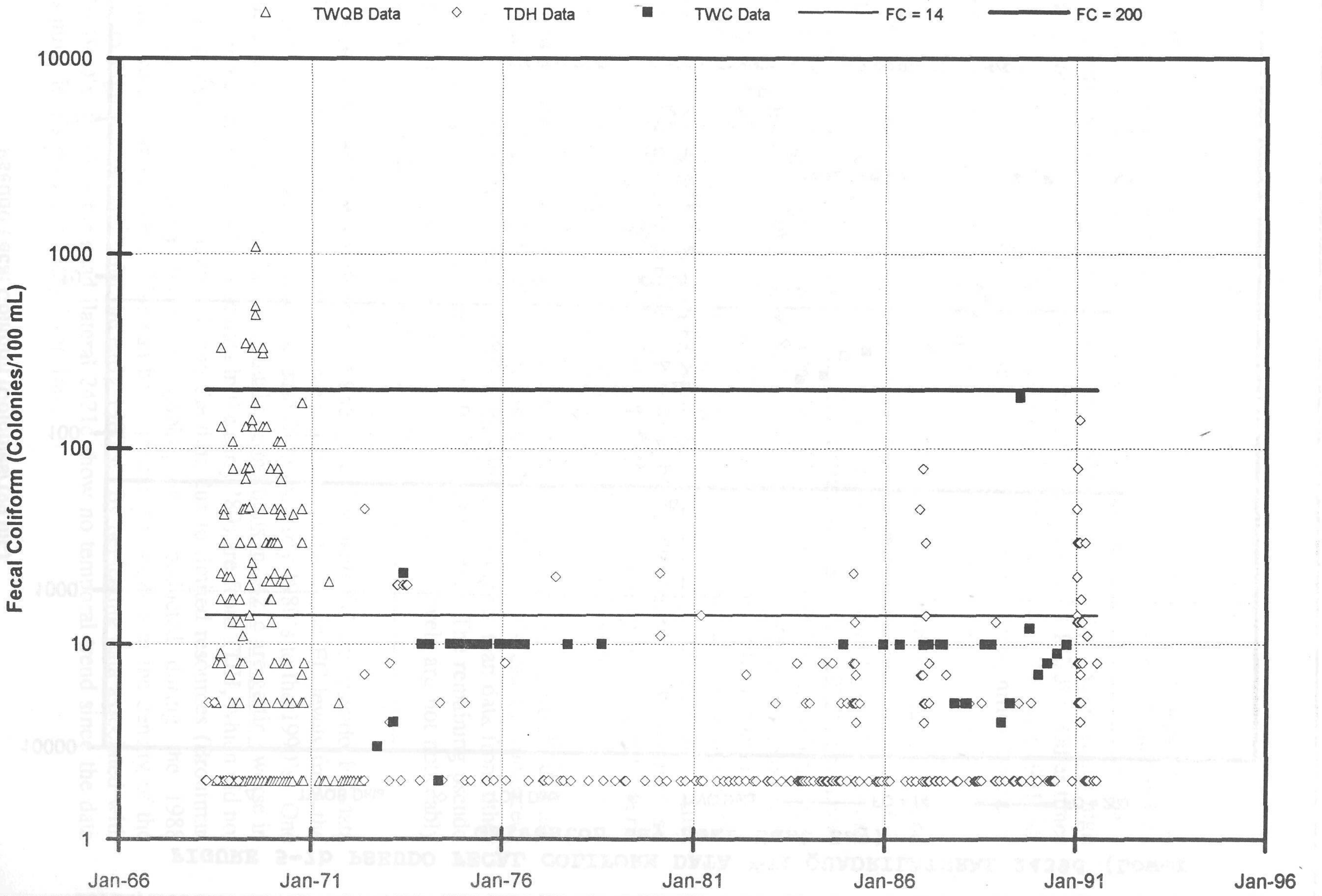
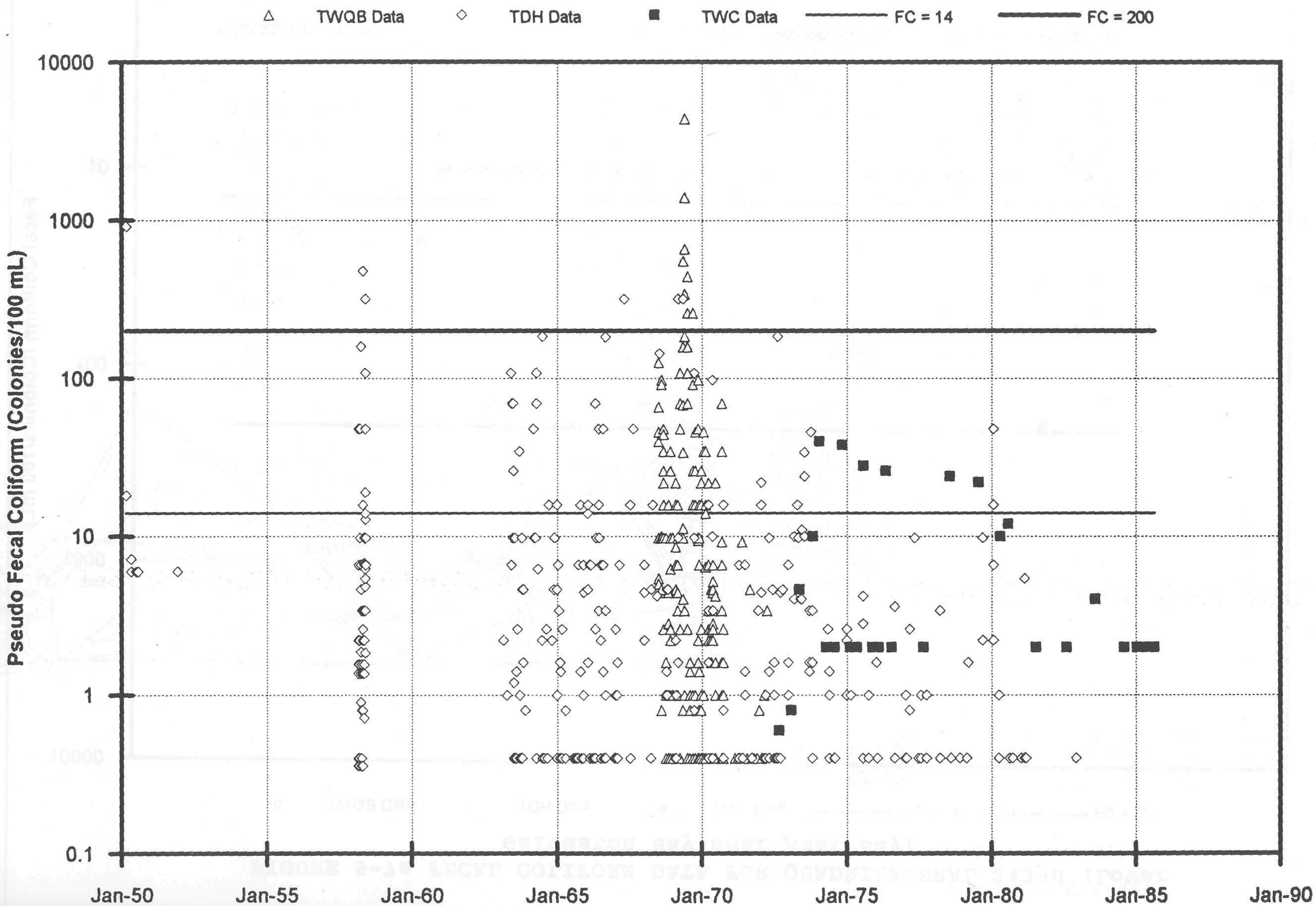


FIGURE 5-7b PSEUDO FECAL COLIFORM DATA FOR QUADRILATERAL 2439d (Lower Galveston Bay Near East Bay)



many if not most of the observations from TDH are 2 FC/dL, as would be expected in an area approved for shellfish growing with little development. A second point is that periods of higher FC levels are clustered at specific times. One such time is the intensive monitoring activity during the original Galveston Bay Project. While some fairly high values are reported, the geometric mean of the TWQB data is 7.72 FC/dL. Other times with some high coliform levels are the TDH observations in 1958, 1986, and 1991, all very wet years. It is concluded that in the control area, there is no significant trend in indicator bacteria levels.

The second trend analysis was done on quadrilateral 2421b, as shown in Figures 5-8a and 5-8b for FC and pseudo FC data respectively. For FC, there are only data from TWQB and TDH, with no TWC stations in this area. A first impression from Figure 5-8a is that the FC data seem to decline through time with higher values in the 1970's and lower values in the 1980's and 1990's. However, the high values of FC data are mostly from the TWQB source which, after checking the locations of the sampling stations, were sampled right at the mouth of the Houston Ship Channel where the coliform concentration can be expected to be high, especially in the early 1970's. If these data are excluded the declining trend is no longer obvious. Two conclusions can be drawn on the water quality condition for quadrilateral 2421b. One is that when consistent stations are considered, no significant trend can be observed. The second is that the boundary of this quadrilateral needs to be redefined to avoid including the small slice of the ship channel.

Although the long-term mean FC level for quadrilateral 2421b is high, pseudo FC data are still provided in Figure 5-8b so that coliform levels in the 1960's can be compared. Similar to the FC data, the pseudo FC data from TWQB are higher than data from other sources and are not considered representative for the entire area. The remaining pseudo FC data in Figure 5-8b show no significant trend. Also, their levels are not noticeably different from the FC levels shown in Figure 5-8a.

Figures 5-9a and 5-9b give plots for quadrilateral 2421c with FC and pseudo FC data respectively. From Figure 5-9a, the data seem to show a decline in FC levels from the 1970's to the early 1980's and then an increase from the early 1980's to the 1990's. One might jump to a conclusion that the water quality conditions in 2421c are getting worse in the '90s. However, most lower value data in the early '80s are from TDH, which did not perform intensive coliform sampling during the time due to limited resources (Broutman and Leonard, 1988). More intensive sampling was conducted during the 1988 comprehensive sanitary survey. This can be confirmed by looking at the density of the data in both Figures 5-9a and b for the early 1980's. By neglecting data associated with the early 1980's, the data for quadrilateral 2421c show no temporal trend since the data are on similar levels before and after that time.

FIGURE 5-8a FECAL COLIFORM DATA FOR QUADRILATERAL 2421b (Upper Galveston Bay Near La Porte)

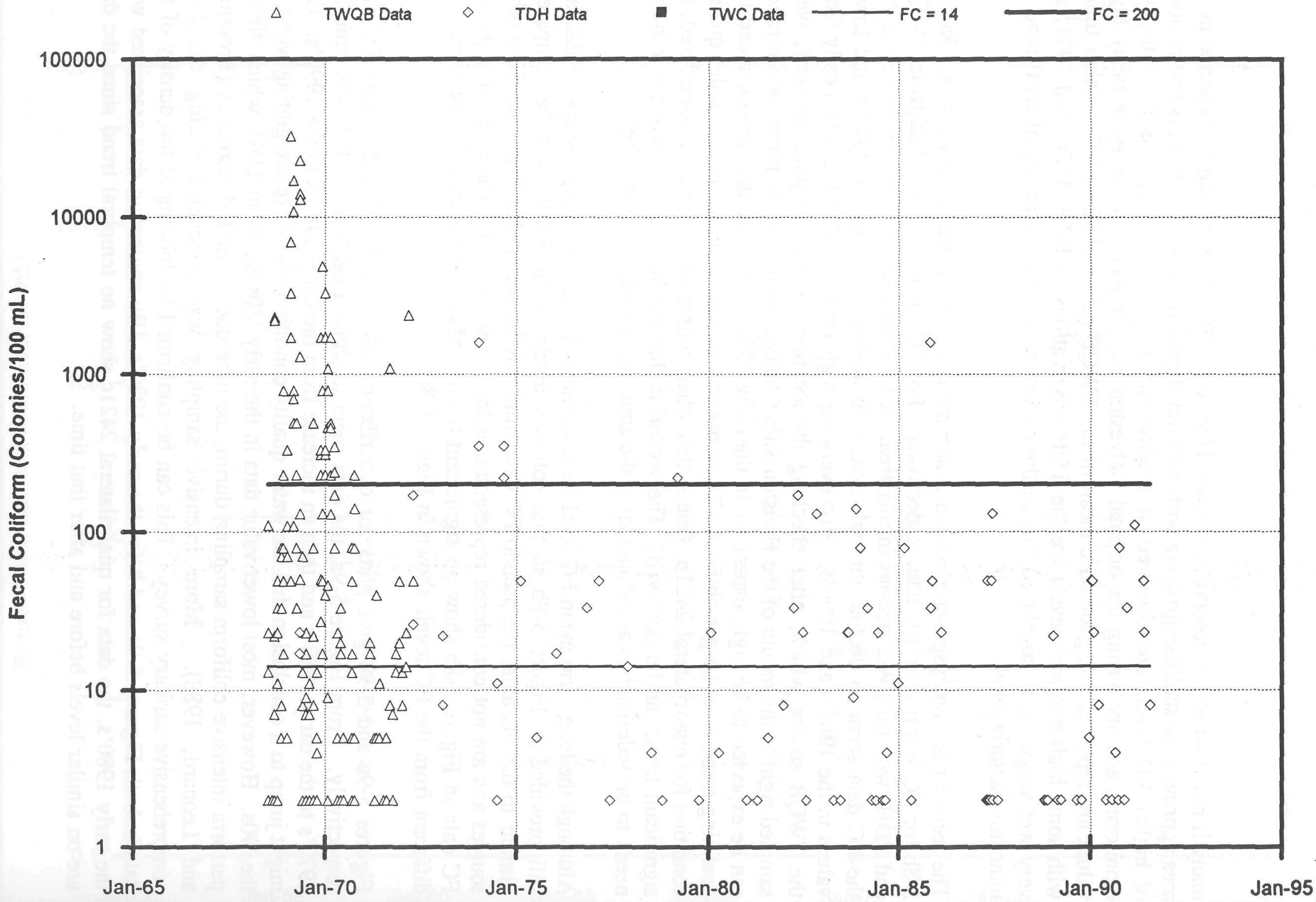


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FIGURE 5-8b PSEUDO FECAL COLIFORM DATA FOR QUADRILATERAL 2421b (Upper Galveston Bay Near La Porte)

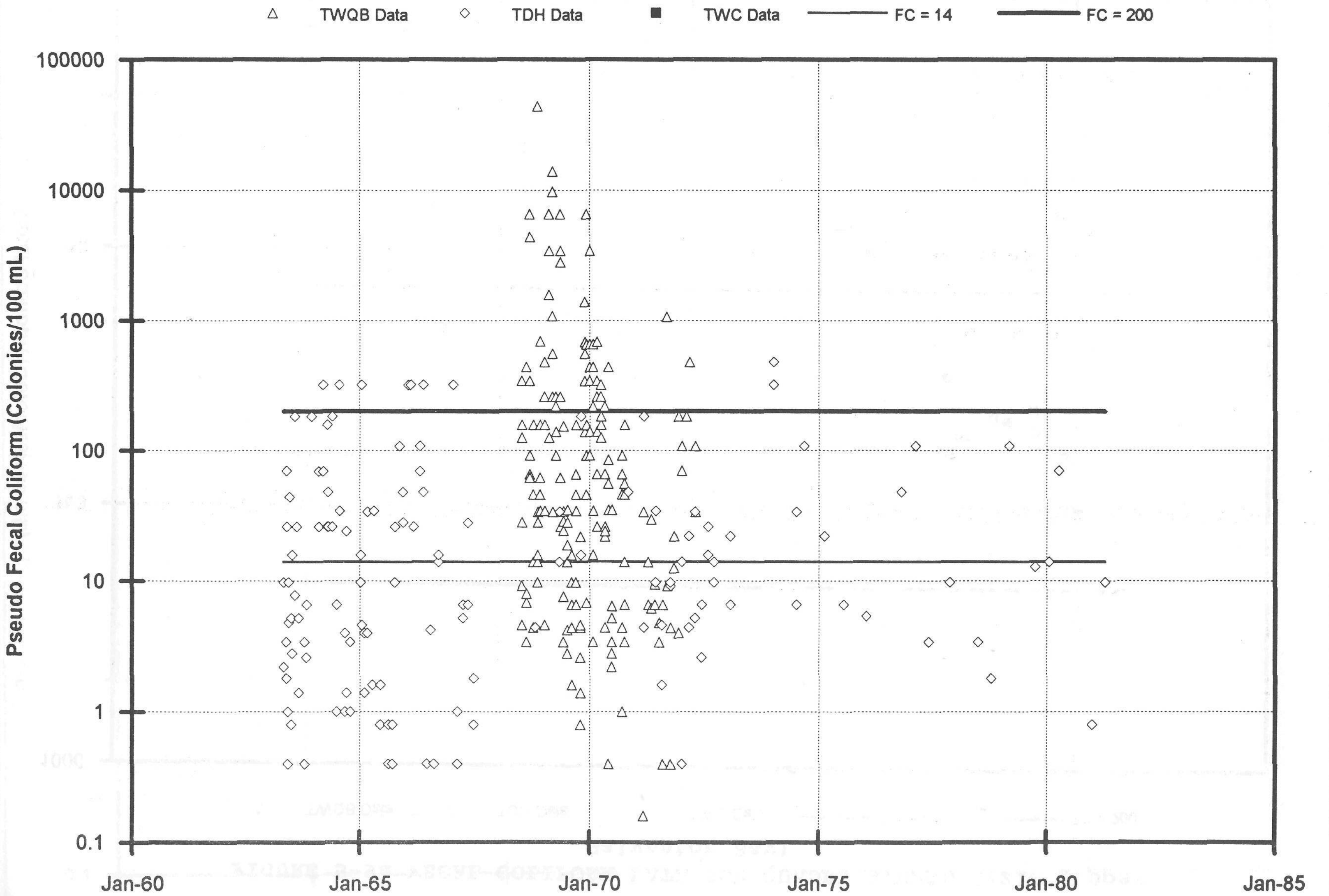


FIGURE 5-9a FECAL COLIFORM DATA FOR QUADRILATERAL 2421c (Upper Galveston Bay)

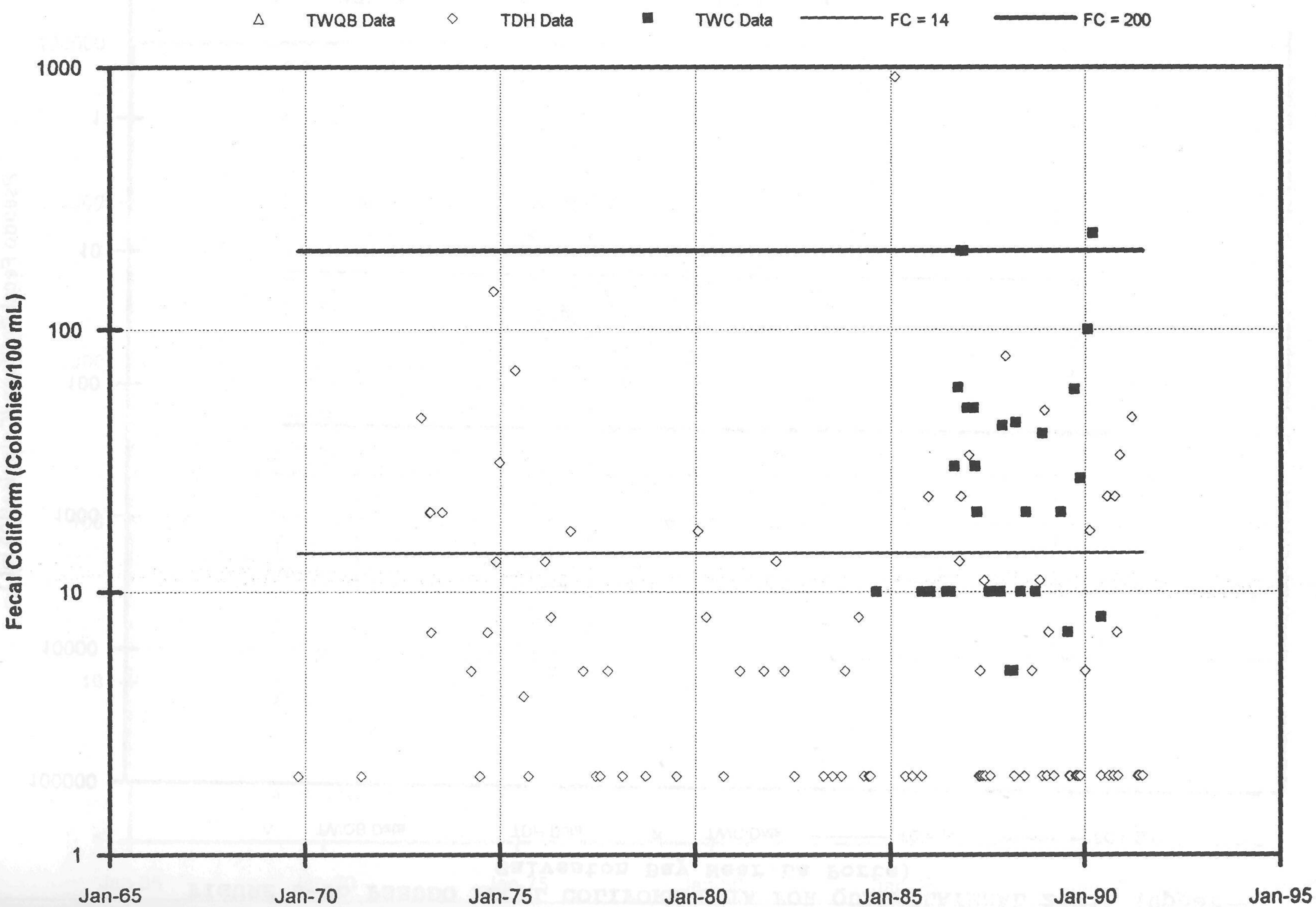
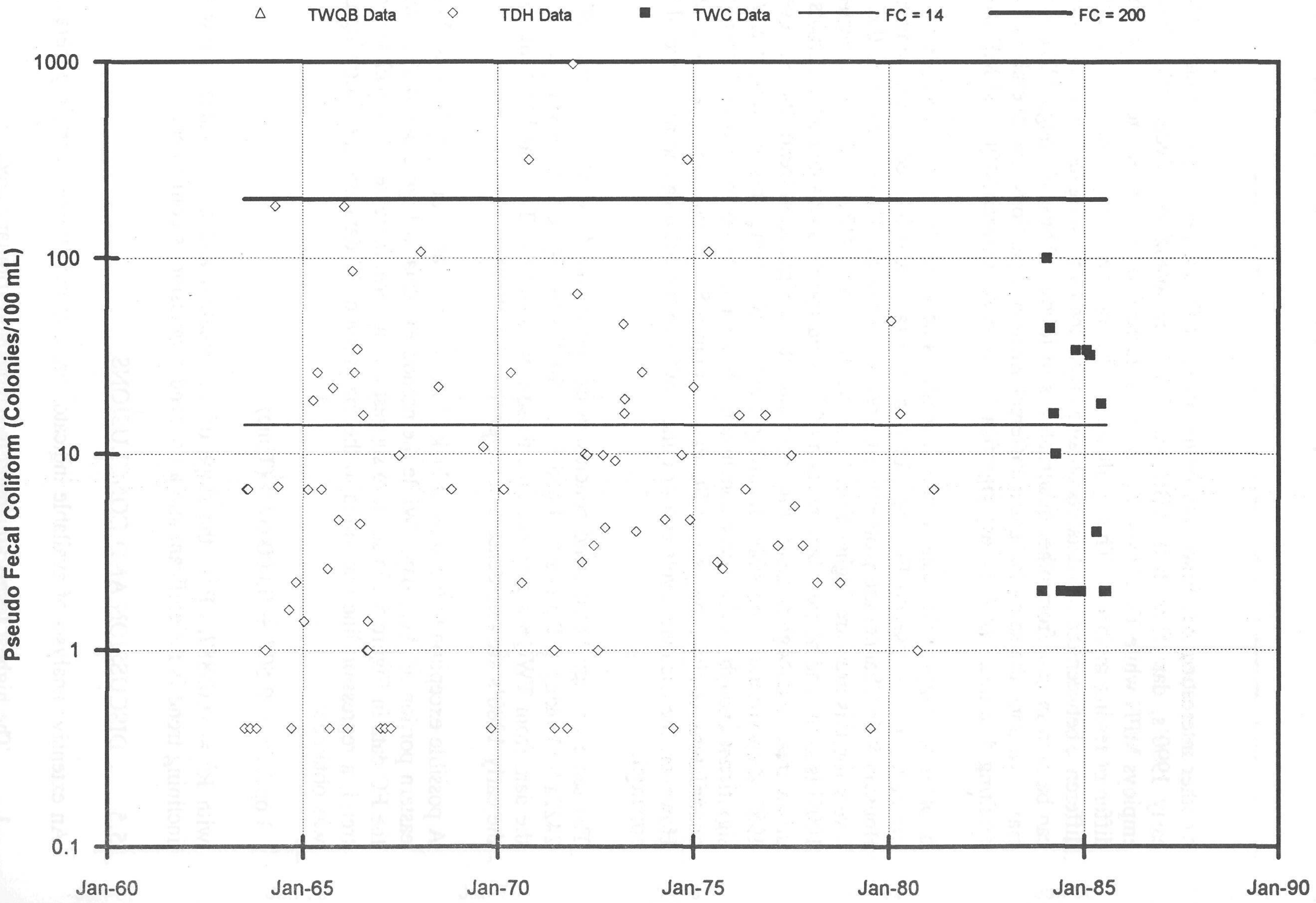


FIGURE 5-9b PSEUDO FECAL COLIFORM DATA FOR QUADRILATERAL 2421c (Upper Galveston Bay)



Another interesting conclusion can be drawn from Figure 5-9a. For the late 1980's and early 1990's, data from both TDH and TWC are available. Recall that since TDH employs MPN while TWC uses MF methods, these data can be used to compare the two different testing methods. The result shows that on the average there is no significant difference between the two datasets obtained from the two testing methods. Similar results can be seen in data from other quadrilaterals to follow. Thus, although TDH and TWC may have done the sampling under different weather conditions, the overall view of the resulting data does not show any significant difference between MPN and MF methods.

In order to compare the water quality conditions between the Houston Ship Channel and the bay, FC and pseudo FC data for quadrilateral 1005i located at the mouth of the Houston Ship Channel are plotted in Figures 5-10a and b. These plots show that the FC levels for this area are higher than those on 2421b and 2421c. This is expected since 1005i is at the end of the inland portion of the Houston Ship Channel which drains a large urban area. Although in general the data indicate no significant trend, the FC levels after 1987 demonstrate a possible declining trend. However, this possible trend is not significant enough to draw any conclusion. Since the long-term mean FC level for this quadrilateral is high, the pseudo FC data in Figure 5-10b must be viewed with caution. However, the absolute levels appear quite similar to the FC data and no temporal trend is apparent.

The same no significant trend conclusion can be obtained for quadrilaterals 2421d and 2422a by looking at Figures 5-11 and 5-12. Similar to Figure 5-9, these figures show that the data from TWQB are higher than those from TDH and TWC and that the data from the early 1980's are less dense and lower than the others.

A possible exception to the general lack of trend is the data from quadrilateral 2424d, the eastern portion of West Bay. While the pseudo FC data in Figure 5-13b show no trend, the FC data in Figure 5-13a seem to suggest a long-term increase. To check this possible trend, a regression line was fitted to the logarithmic FC data and the following equation was obtained:

$$\mathrm{Log}(FC) = 0.507 + 0.000052 * (\mathrm{Time})$$

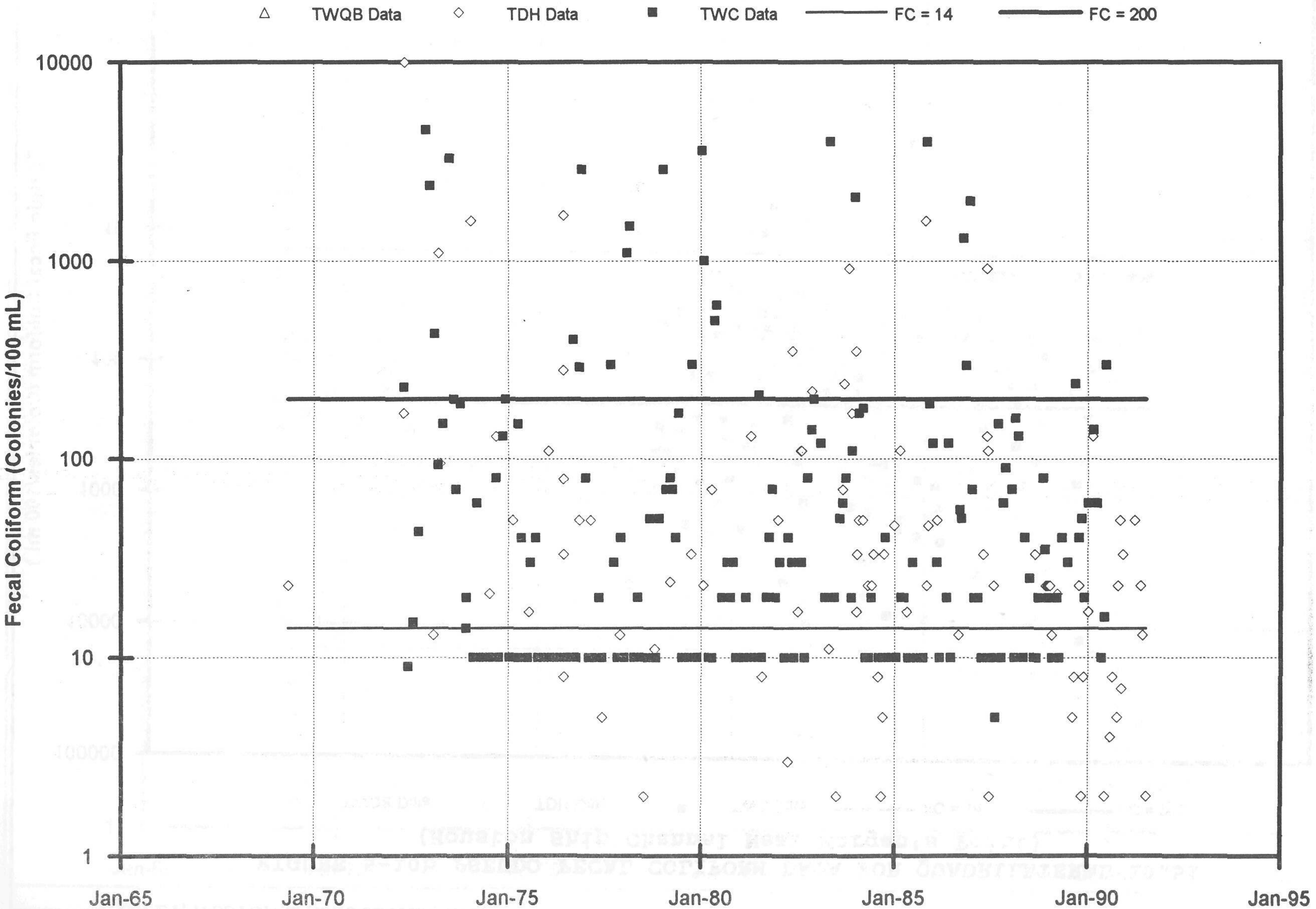
with $R^2 = 0.03887$. Both the slope of the equation and the R^2 values show that the inclining trend is insignificant and a no-trend conclusion is confirmed.

5.5 DISCUSSION AND CONCLUSIONS

An extensive analysis of available indicator bacteria data suggest certain generalizations:

1. The highest levels are found in bayous and tributary creeks,

FIGURE 5-10a FECAL COLIFORM DATA FOR QUADRILATERAL 1005i (Houston Ship Channel Near Morgan's Point)



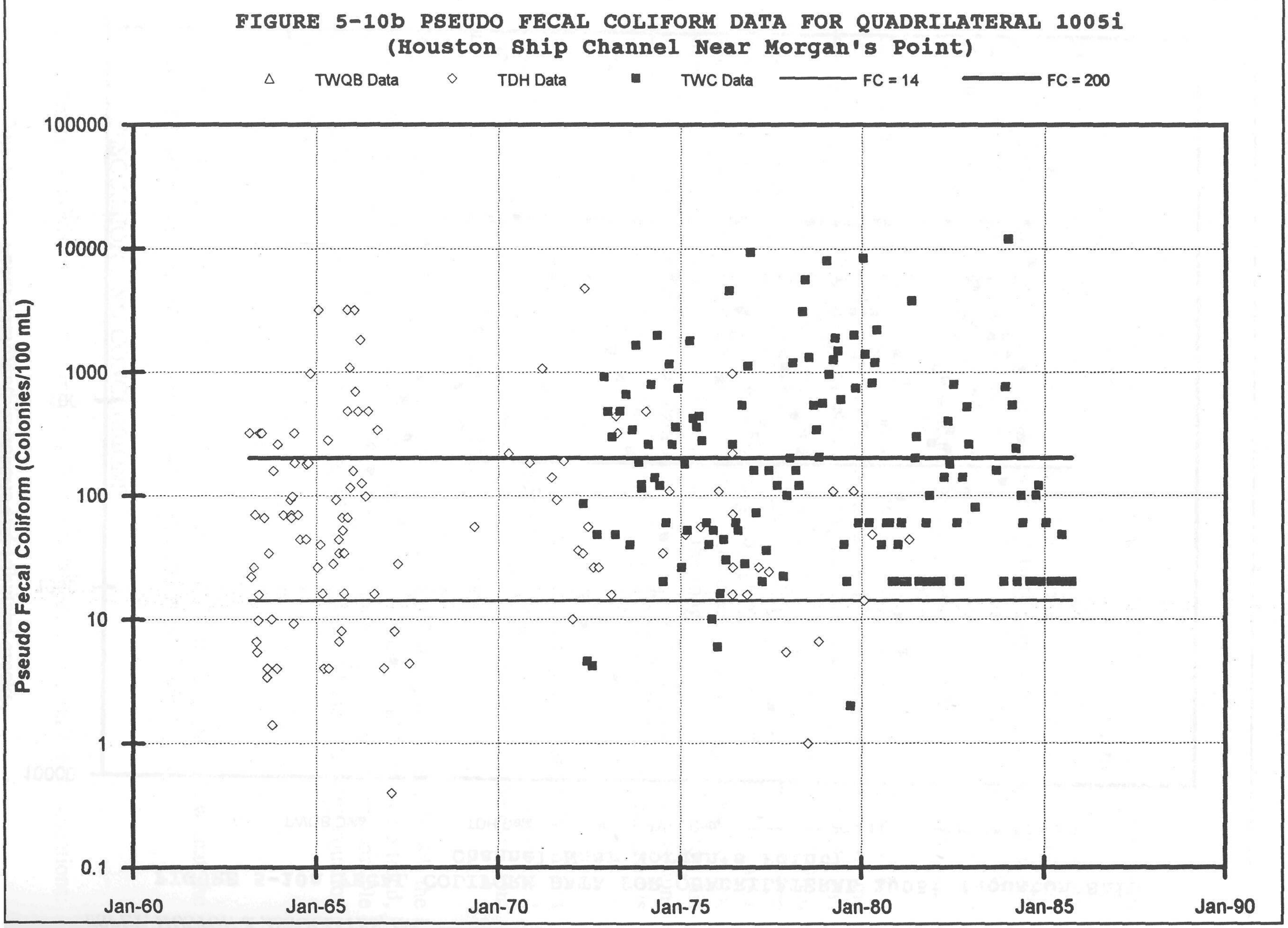


FIGURE 5-10b PSEUDO FECAL COLIFORM DATA FOR QUADRILATERAL 1005i
(Houston Ship Channel Near Morgan's Point)
TWQB Data
TDH Data
TWC Data
FC = 14
FC = 200
Pseudo Fecal Coliform (Colonies/100 mL)
100000
10000
1000
100
10
1
0.1
Jan-60
Jan-65
Jan-70
Jan-75
Jan-80
Jan-85
Jan-90

FIGURE 5-11a FECAL COLIFORM DATA FOR QUADRILATERAL 2421d (Upper Galveston Bay Near Seabrook)

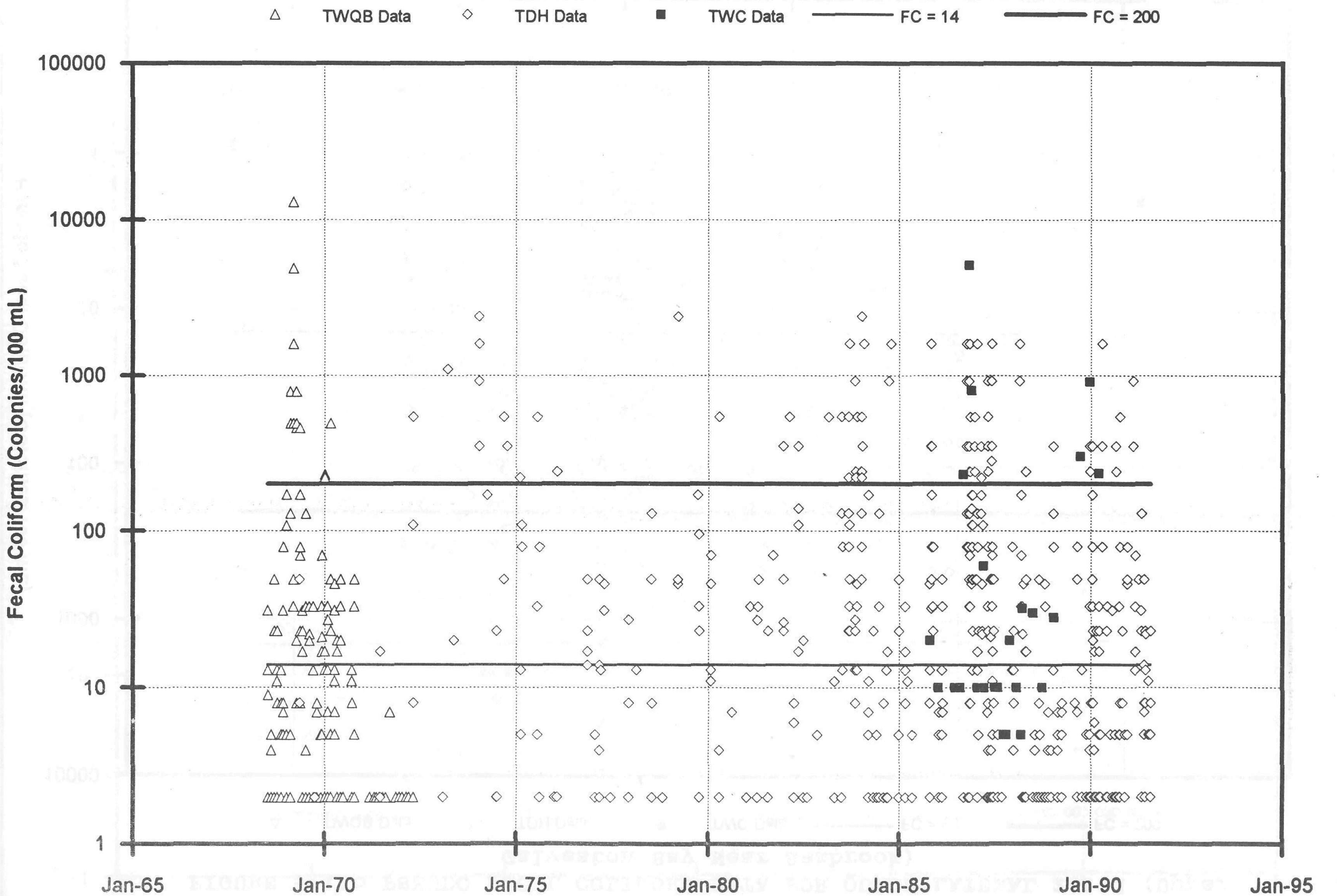


FIGURE 5-11b PSEUDO FECAL COLIFORM DATA FOR QUADRILATERAL 2421d (Upper Galveston Bay Near Seabrook)

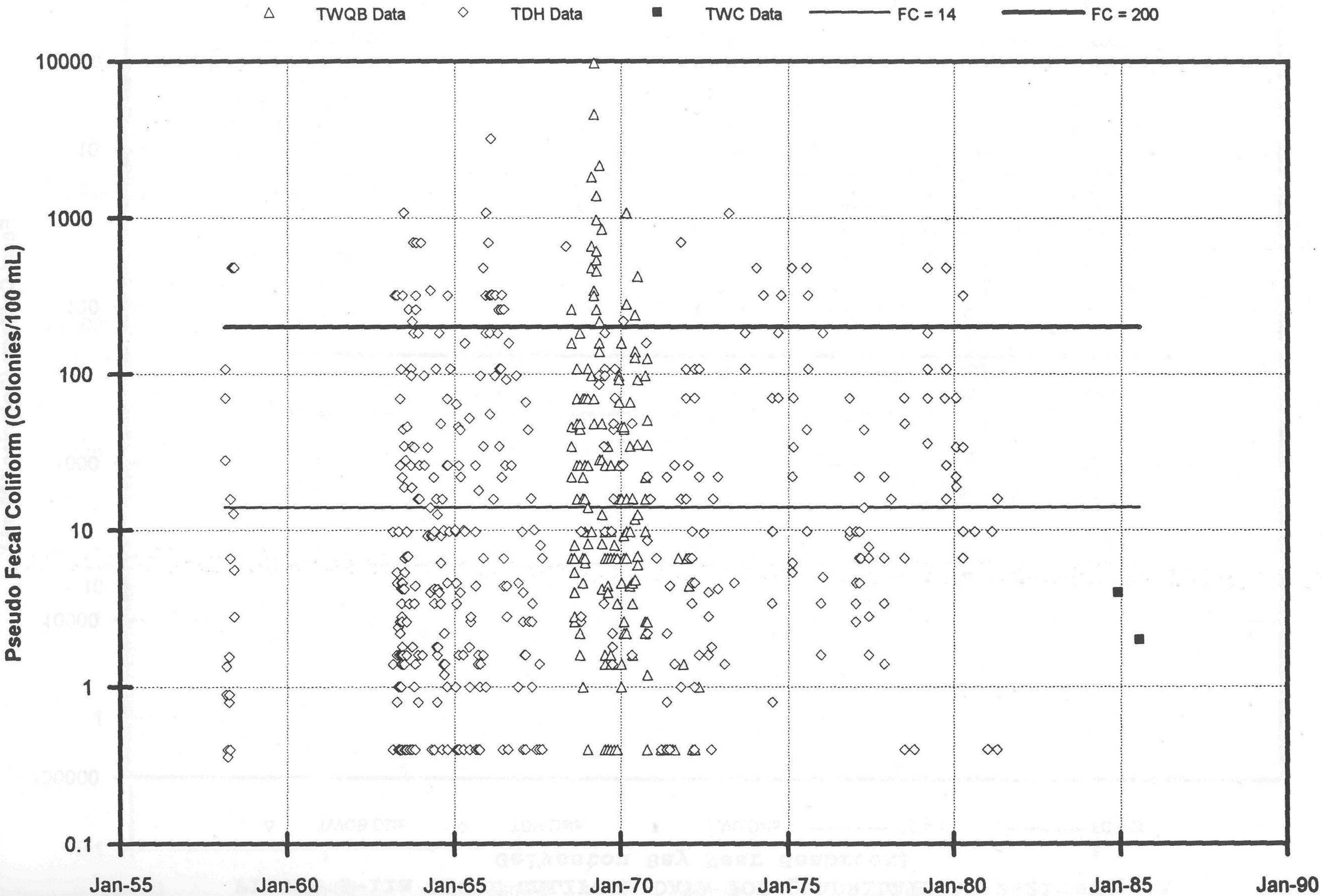


FIGURE 5-12a FECAL COLIFORM DATA FOR QUADRILATERAL 2422a (Trinity Bay)

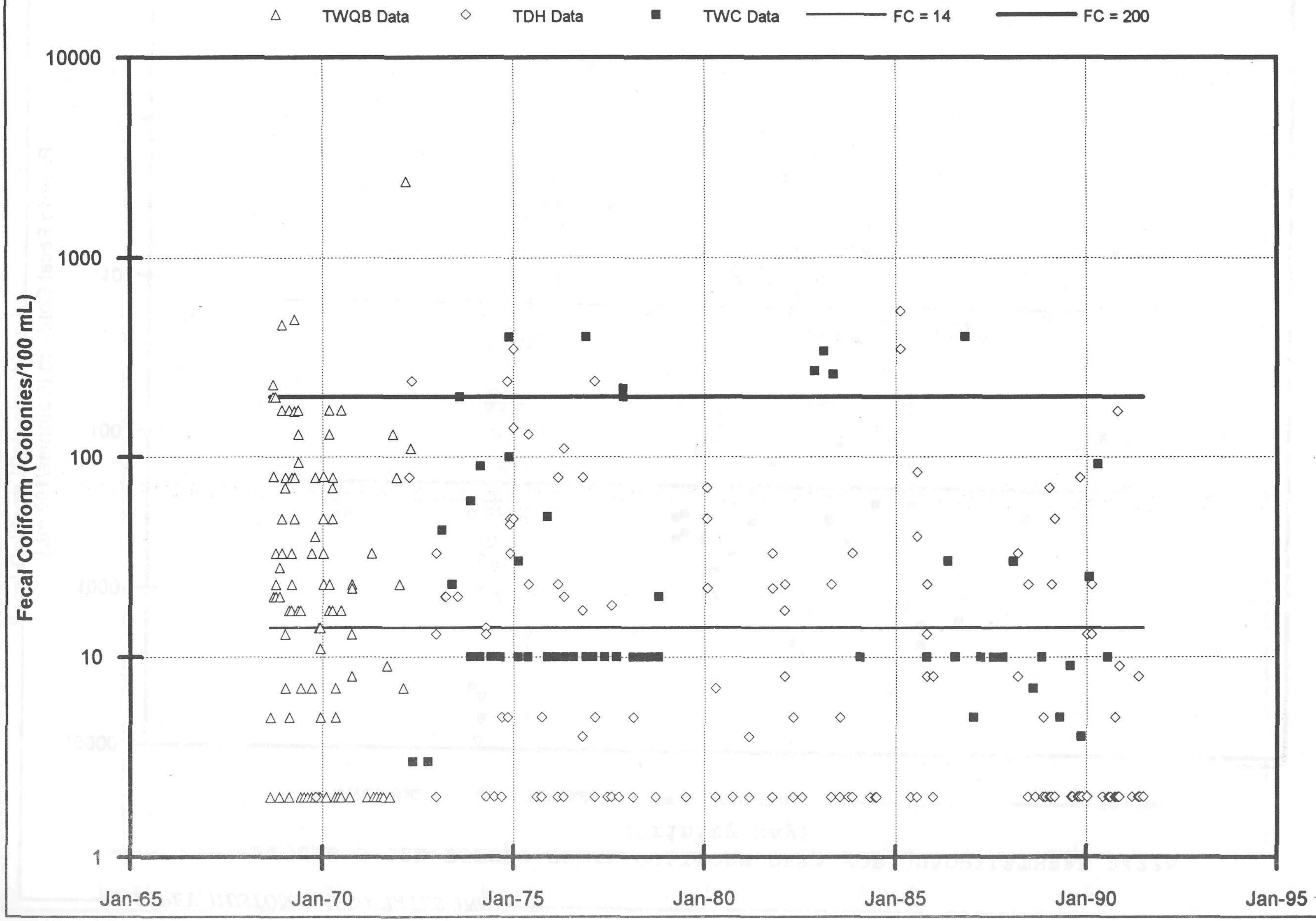


FIGURE 5-12b PSEUDO FECAL COLIFORM DATA FOR QUADRILATERAL 2422a (Trinity Bay)

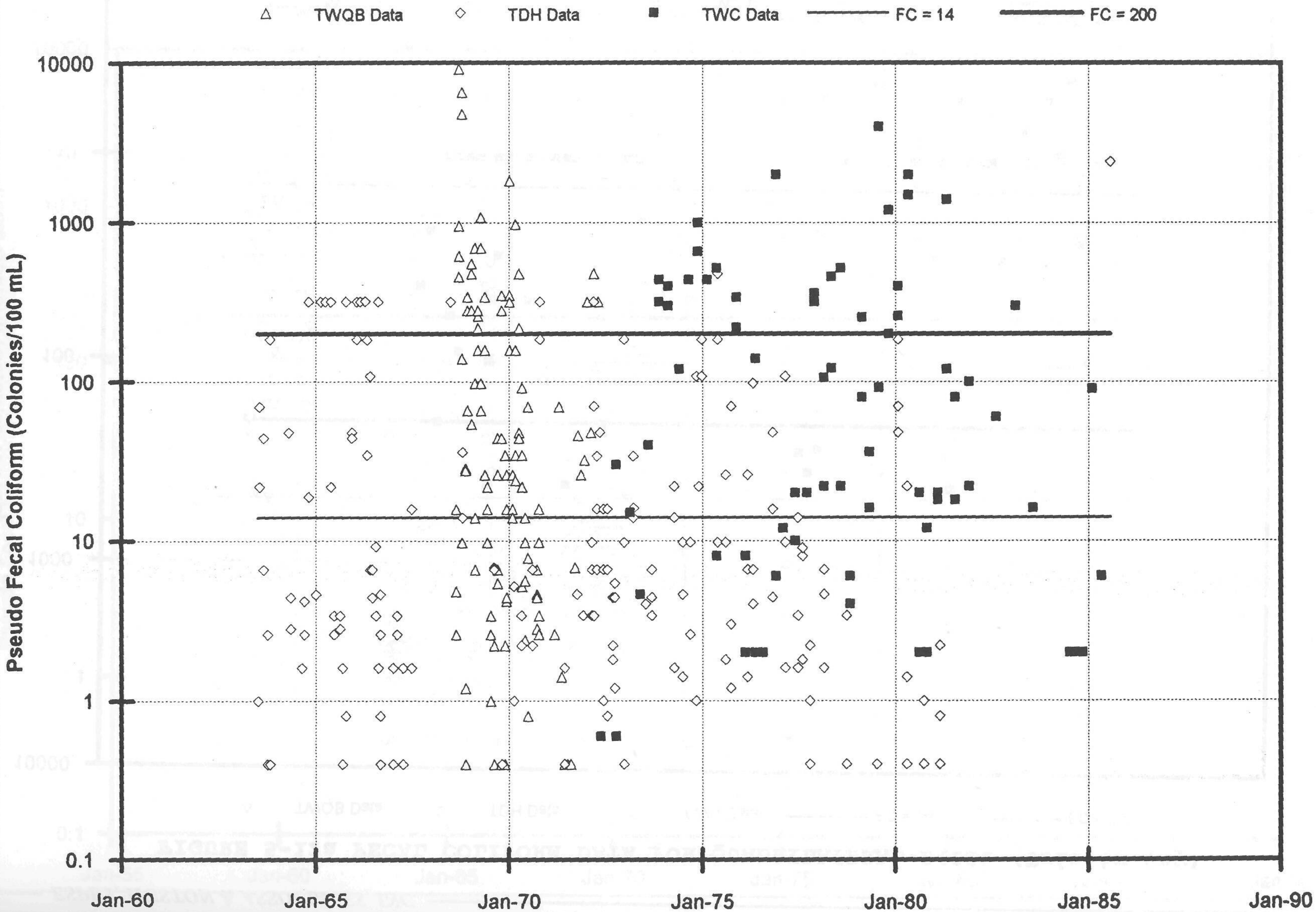


FIGURE 5-13a FECAL COLIFORM DATA FOR QUADRILATERAL 2424d (East Part of West Bay)

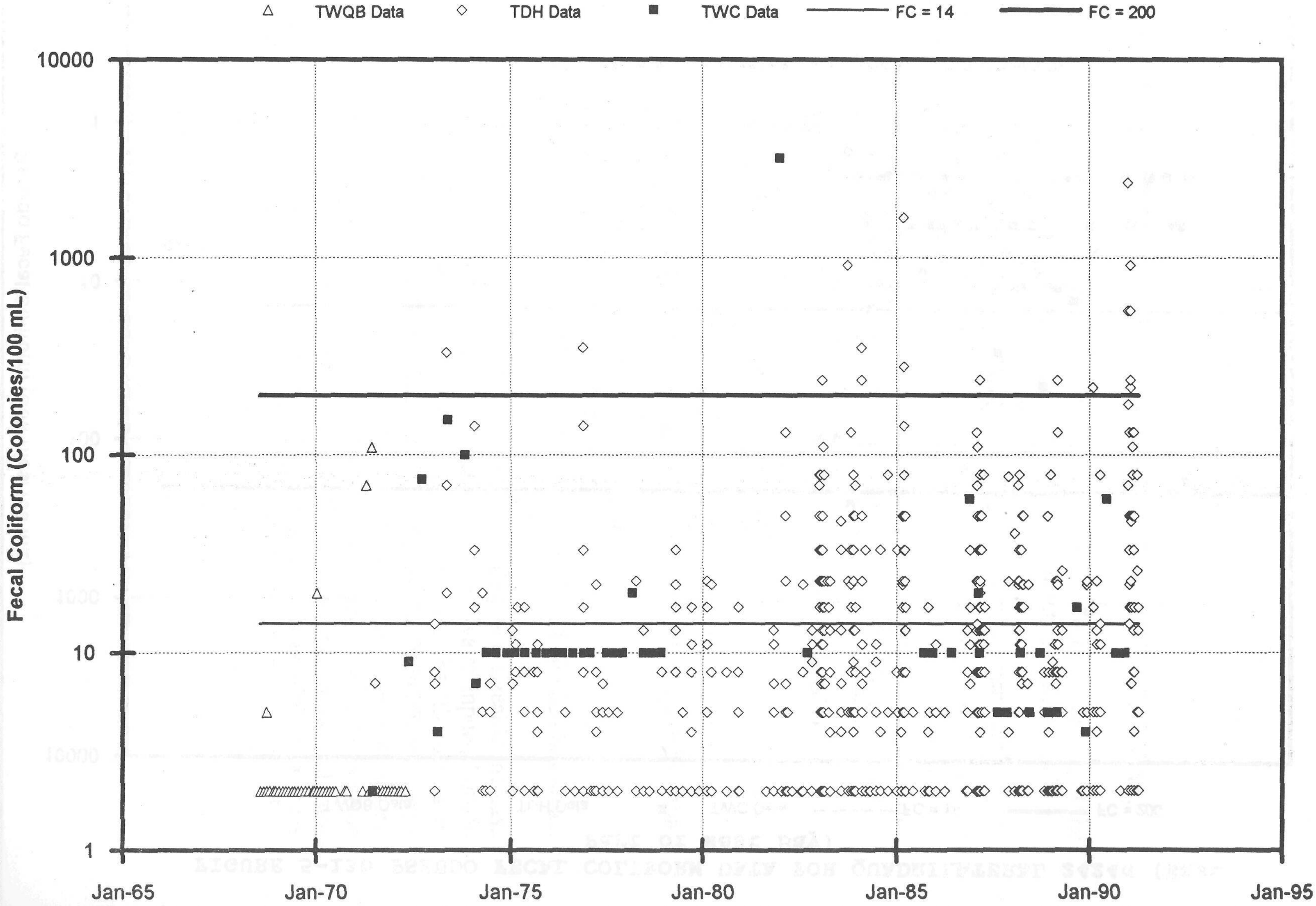


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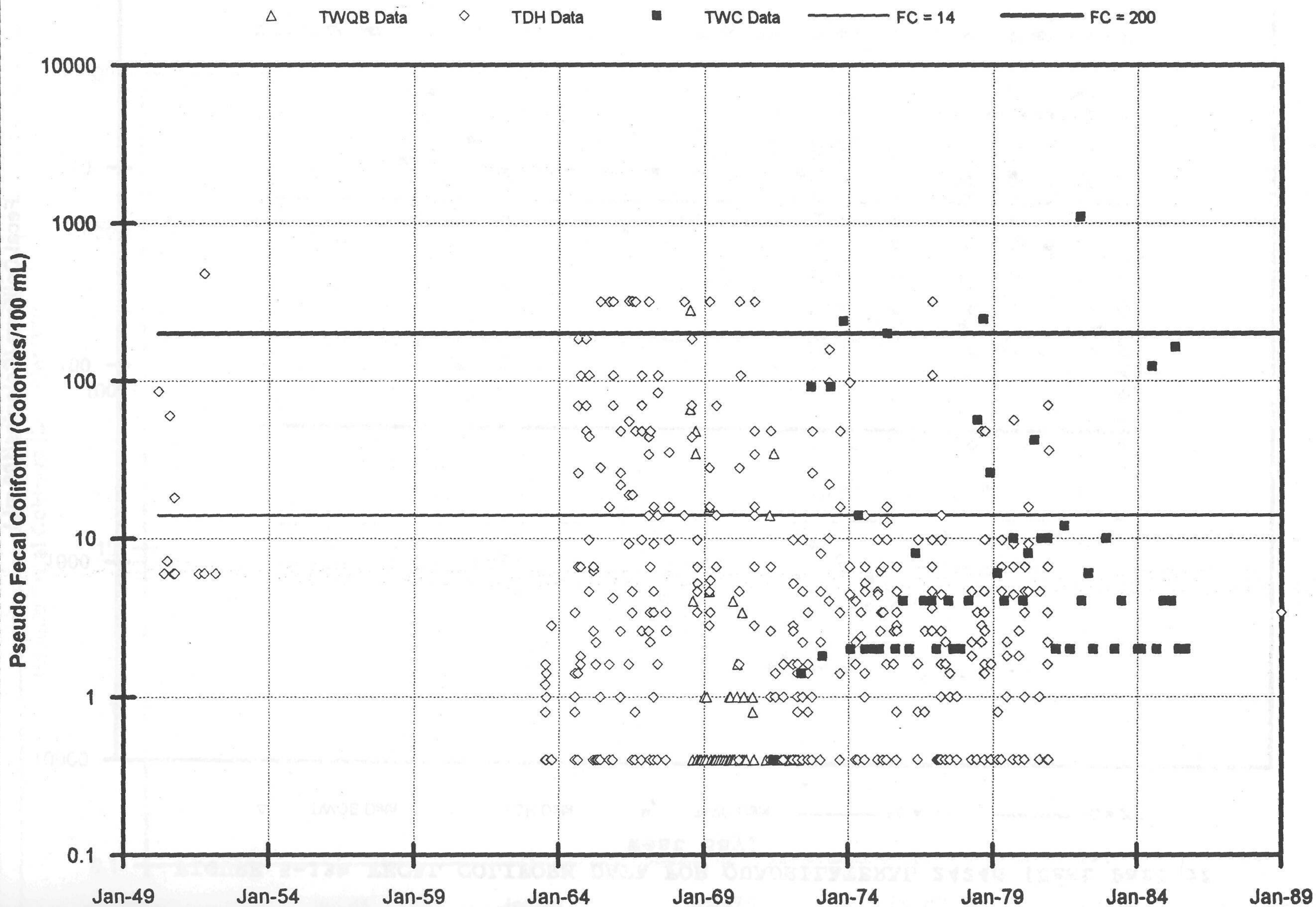
FIGURE 5-13b PSEUDO FECAL COLIFORM DATA FOR QUADRILATERAL 2424d (East Part of West Bay)



2. The urbanized tributaries have higher levels than rural,

3. The highest levels of indicator bacteria occur following heavy runoff events,

4. While 23 out of 73 quadrilaterals have long-term means >200 col/dL, all of the open bay segments currently meet state criteria for contact recreation, and

5. A total of 51 quadrilaterals out of 73 have long-term mean FC levels >14 col/dL. However, almost all of these areas are tributary bayous which do not support shellfishing. A substantial number of open bay areas which support shellfish populations are closed to harvesting either because more than 10% of the data exceed 43 col/dL or as a precaution due to proximity to human activity.

6. There is no descernable temporal trend in any of the data analyzed.

These observations are entirely consistent with the findings from the previous section on sources of indicator bacteria:

1. Runoff, carried by rivers and bayous, is the dominant source of indicator bacteria,

2. Urban runoff is larger than runoff from other land uses, and

3. Runoff dominates tributary segments but has much less effect on open bay areas.

From these observations and findings, one can conclude that, despite a sizeable increase in population surrounding the bay and substantial modifications of water inputs, both in timing and location, there has been no discernable effect on public health aspects of Galveston Bay, at least in terms of indicator bacteria. While there has been improvements in the level of wastewater treatment, the major reason for this appears to be that natural sources for indicator bacteria so dominate in bay areas that changes in anthropogenic inputs, which have undoubtedly occurred, cannot be detected. To the extent that indicator bacteria are indicating the presence of natural microorganisms, it is possible that some regulatory effort based on indicator bacteria is being misplaced.